Electrical Railroading

OR

ELECTRICITY AS APPLIED TO RAILROAD TRANSPORTATION

BY

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ILLUSTRATED

CHICAGO
FREDERICK J. DRAKE & CO., PUBLISHERS
1908

PREFACE.

This book is written principally for railroad men who are or may some day be in contact with the electrical machinery and apparatus, which is today installed on all steam roads, and with the machinery and apparatus which is being or will be installed by many roads with the intention of using electricity as a motive power on branches or even sections of their main line.

Nearly all roads use both telegraph and telephone in controlling train movement; all use telegraph and electric bells. Many roads are using electrically controlled block signals, and the use of automatic electric signals is rapidly increasing.

It will not be long before electricity will become the motive power in use by the roads entering the large cities on all their urban and suburban lines. The electric locomotive and motor car will supersede the steam locomotive.

No railroad man, engineer, conductor, fireman, baggageman, switchman, brakeman, towerman or any other, can afford to be ignorant of the subject of electricity. The men who know most about it will stand the best chance.

The men who study will possess knowledge of electricity that can not fail to be of immense advantage to them in the next few years.

It will make them more valuable to the companies, and keep them abreast of their rapidly developing profession.

It would be impossible to exaggerate the importance

of such preparation being made by the men who wish to succeed. To be content to be ignorant of electricity and its application to motive power, is to be doomed, or to doom yourself to failure.

There are, however, many other men who are interested in electricity as applied to railroads and for such the book is also written.

Considering the recent date of the adaptation of electrical power to steam roads, all descriptions of old-fashioned machinery and apparatus which we would find in many electric light or street railway plants are omitted and the descriptions of apparatus to be found in large traction plants, whether inter-urban, branch or main line stations, will be described in full, and in such a way that it is hoped that any still newer types of machinery and apparatus, will be understood because of the fundamental knowledge gained by study of this book.

METHOD OF THE BOOK.

The author has endeavored to be honest as to what we know about electricity and what we think we know; also to tell the things a railroad man should know plainly.

The book consists of a series of lessons, each one of which should be learned before studying the next.

Each lesson is short enough to be studied at one time. When a reference is given to a lesson ahead it is to be simply read, not studied. In fact, the student need not look up the reference if he is in a hurry to finish the lesson.

These references will, however, be an extra help in making the lessons easily understood. Whenever a word or term is used for the first time it will be explained at once, in the text or by foot note, or else a reference ahead will be given. After a word has been used and explained no reference will be given.

The style is a series of questions and answers.

The questions are those which would be asked by a person seeking information about electricity and electric railroads, and the answers are those which would be given by one teaching electricity to the questioner.

Thus by learning the answers a person gains a knowledge of electricity and also the art of explaining things to other people. This is of inestimable value to any man, because when we are compelled to tell a friend "I know it but I can't explain it," we are apt to fall in that person's estimation. He either thinks that we do not know or will not tell.

Many of the questions in these lessons are ones which have actually been asked the author by acquaintances and students. He feels greatly indebted to the railroad men of one of the large terminals who, while receiving instructions from him in Electricity as Applied to Railroad Transportation, helped him wonderfully by their readiness to ask questions until they understood what was told them.

The book is not offered with a faint hope that it may succeed, but knowing that what it contains has helped a group of railroad men, it is hoped that, put in a book, it will reach more men and be of use to them.

The introductions to the lessons are those parts which prepare the student's mind for the lesson, and they contain information which can be told better in that way than by questions and answers.

Descriptions of apparatus and machinery are often given between lessons. These not only make the student familiar with the things described, but serve to fix the knowledge already attained. The study of these descriptions also reviews the knowledge previously acquired.

LESSON I.

INTRODUCTION.

Exactly what electricity is we do not know, and indeed a practical man always dealing with the useful effects of electricity, applying these to the necessities and for the comfort of mankind, finds little time to wonder what electricity is.

We will omit the almost unanswerable question:— "What is electricity?"—and proceed to the question.

Question 1. What is meant when a person talks about electricity?

Answer. There are certain effects which we believe to be due to electricity, so that when a person observes any one of these things, he at once declares that there is electricity present.

Question 2. What are some of these effects?

Answer. Lightning during a thunder storm. Lighting gas with a spark from the finger tip.

Question 3. Are these effects due to electricity?

Answer. Yes, but by a kind which is different enough from other electricity to be called *Static Electricity.*

Question 4. Why is it called static electricity?

Answer. Because a quantity of this kind of electricity will remain on a body provided it is hung up by a dry silk thread. This electricity is at rest or *stands still.* Static means standing.

Question 5. What other effects are due to electricity?

Answer. Ringing of an electric bell. Operation of an electric motor.

Question 6. Are these effects due to static electricity?

Answer. No, the bell and motor are operated by *Dynamic Electricity.*

Question 7. What is meant by dynamic electricity?

Answer. Electricity in motion, because the word dynamic means force, giving the idea of motion.

Question 8. What is meant by a *current* of electricity?

Answer. Dynamic electricity is usually referred to as a current of electricity.

Question 9. Are there any other effects said to be due to electricity?

Answer. Yes; the working of a wireless telegraphy instrument.

Question 10. What kind of electricity operates this instrument?

Answer. Electrical waves.

Question 11. Are there still other kinds of electricity?

Answer. Practically no. All the effects we observe may be explained as being caused by either static electricity, a current of electricity or electrical waves.

Question 12. What is static electricity?

Answer. It is electricity at rest.

Question 13. What is current electricity?

Answer. It is electricity in motion along a conductor.

Question 14. What are electrical waves?

Answer. They are electricity moving through the air, no conductor being required.

Question 15. Does the word electricity in the last three answers mean the same thing in each?

Answer. Yes; in each case it is electricity, either at

rest, moving along a wire, or moving through the air without a wire.

Question 16. Give an example of static electricity.

Answer. If a brass ball be suspended by a silk thread and touched to one knob of an electrical machine (see Lesson 6) and then removed, it will be covered with a charge (see Lesson 2) of electricity. This electricity will be at rest and so is called a charge of static electricity.

Question 17. Give an example of a current of electricity.

Answer. If quantities of electricity are supplied at the end of a metal wire, they will quickly flow to the other end. Here the electricity is in motion and a current of electricity is flowing.

Question 18. Give an example of electrical waves.

Answer. If electricity is forced by a high pressure as in an electric machine or in an induction coil (see Lesson 27) to jump a spark across an air space, while doing so it will send out in every direction a series of electrical waves which will travel long distances without the aid of wires.

Question 19. What are some of the common effects of current electricity?

Answer. Heat, light, magnetism, metal plating and refining, and medical effects.

Question 20. Explain about the heat effect.

Answer. If large quantities of electricity are forced through a conductor in a short time the wire is *heated.* The poorer the conductor the more heat is produced.

Question 21. Is there always some heat produced?

Answer. Yes. Electricity cannot flow through a conductor without producing some heat.

Question 22. Are the wires in a building heated, while carrying electricity?

Answer. Yes; but the wire is large compared with the current carried; the material is copper, a good conductor, so that the heating is too small to be detected by feeling the wire.

Question 23. Does electricity produce light?

Answer. Yes. The heat produced in a very poor conductor by the current may be so great as to burn the conductor and the flame gives light; or it may make the conductor white or yellow hot, thus giving light.

The arc lamp gives light from flame and white hot carbon, while the incandescent lamp has no flame only the yellow hot carbon.

Question 24. Does electricity produce magnetism?

Answer. Yes. Electricity in motion will always affect the needle of a compass, usually pulling it aside from the north and south line, and keeping it out. This is described as "deflecting the needle" and whenever the "magnetic needle" is spoken of we mean a magnet of small weight and fairly long, pivoted so as to move freely in a horizontal direction. We speak of this effect as ***electro-magnetism.***

Question 25. How does electricity plate metal?

Answer. Electricity in passing through solutions of chemicals takes the metal out of the solution and turns it into the solid form, thus making a layer of metal on the object placed in the solution. (See Lesson 17.)

Question 26. How does electricity refine metals?

Answer. If a lot of metals and other chemicals are in a solution, by passing electricity through the solution the metals will be solidified and may be removed while the other chemicals remain dissolved in the solution.

Question 27. What are the medical effects of electricity?

Answer. They are not well understood; but the passage of current through the body seems to have a curative effect on some diseases.

Introduction to Static Electricity.

Static electricity is of importance to the railroad man in many ways.

In power houses and machine shops the belts often produce static electricity so that a person going near or under them will receive a rather unpleasant shock.

A locomotive blowing off steam through the safety valve becomes electrified but the charge is much too small to give any one a shock.

Lightning is static electricity and consists of such large charges that electrical machinery is usually badly damaged if lightning passes through it.

The telegraph, telephone and signal circuits, the power lines, and all buildings into which wires enter must be protected by lightning arresters.

Motor cars and electrical locomotives must be equipped with lightning arresters to protect their wiring, apparatus and motors.

A great many of the cables distributing electricity, especially at large railroad terminals, or along the right of way in the city limits are carried in conduits underground. To protect them from moisture they are covered with lead. This lead sheathing often collects electricity and heavy static discharges take place.

The discharge may injure instruments and apparatus connected to the cables or may even injure the power house or line men while handling the cables or switches attached to them.

A proper arrangement of lightning arresters and static dischargers will prevent this.

It will be seen that a thorough understanding of static electricity is a good thing for a railroad man.

There are three pieces of apparatus which are easily made, and the use of which will help one to readily understand the action of static electricity.

They are the Electrophorous, to produce static electricity; the Leyden Jar, to store electric charges in; and the Electroscope, to detect the presence of an electric charge and its polarity.

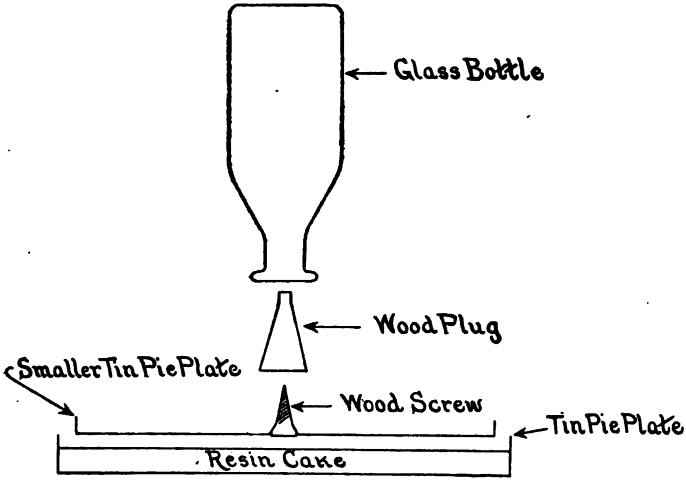

Fig. 1. Construction of an Electrophorous.

THE ELECTROPHOROUS.

Melt a mixture of two-thirds rosin and one-third gum shellac or some common red sealing wax,* by setting the dish on hot water. This is to avoid the danger of its catching fire.

* Sealing wax is a mixture of rosin or other resins with vermilion or some other powdered color.

Pour the melted stuff into a large tin pie plate and allow to cool into a solid cake. Slow cooling will prevent cracks, but they really do no harm.

Get a tin pie plate or tin layer cake pan a little smaller in diameter than the resin* cake. Make a wood cone. Screw a large flat head wood screw into the thick end of cone, and then solder it to the tin plate. Fasten it to the inside of bottom of plate.

Whittle the small end of the cone to a driving fit to the neck of a small glass bottle. Press the bottle on gently but firmly.

We now have a glass-handled tin dish to rest on the resin cake, touching it all over, but the two tin plates not touching anywhere.

A piece of flannel or woolen cloth is needed for a rubber.

Leyden Jar.

A large plain beaker should be purchased from a chemists' or druggists' supply house. The "plain" means that there is no lip on the edge. It should be large enough to hold a quart and a half of water. It will be a very thin glass and must be handled carefully to avoid breaking.

Cut tinfoil to fit the inside and outside of the bottom and dry the beaker over a stove or radiator. While dry and warm paste the tinfoil on. Warm it again and paste

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* Resin means any gum that flows from a tree as a sticky liquid and hardens on contact with air. Gum arabic and gum shellac are resins. Rosin is a resin from a pine tree. It is left in the bottom of the stills when the spirits of turpentine are boiled off.

tinfoil over the outside up to about two-thirds its height. Let the side foil lap over the bottom foil.

Cut a piece to fit the inside and roll it around a pencil. Coat the inside with paste to about two-thirds its height with paste or mucilage and stick one end of the tinfoil down. Unwind the foil from the pencil and press it down on paste with fingers or another pencil.

If the side and bottom foils do not connect, paste a strip across the seam.

Take a thin board larger than the mouth of the beaker and dry over a stove and shellac varnish it while hot.

Fig. 2. Leyden Jar.

Warm the beaker and while warm and dry shellac all the glass not covered with foil.

Drill a small hole in the board and insert a short metal rod. Fit to its lower end a piece of chain long enough to touch the foil on the bottom of beaker, when the board rests on its top. Fit the upper end with a metal ball. Any size, solid or hollow makes no difference.

Put a circle of shellac varnish on the under side of board and lay board on beaker so that chain touches bottom.

When shellac dries the board will stick and keep inside of jar dry.

Discharger for Leyden Jar.

Bend a piece of wire like this ~ and stick the doubled part in a cork, put cork in a glass bottle and the result is as good as Fig. 3.

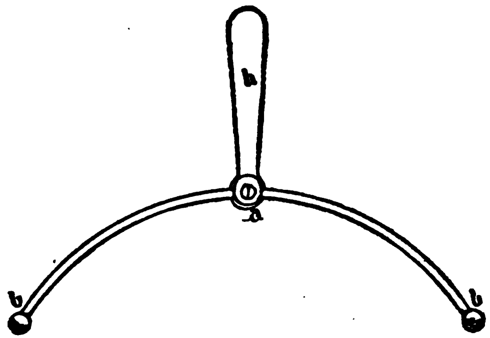

Fig. 3. Discharger or Discharging Tongs for Leyden Jar.

Electroscope.

A wide-mouthed fruit jar is taken and a cork or wood stopper made to a loose fit.

Drill a hole through the stopper and insert a glass tube about four inches long projecting equally on both sides.

Take a small metal rod or heavy wire which will go through the glass tube and hammer one end flat for about half an inch from the end. The thinner and flatter it is made the better.

Insert wire in tube so that the flattened end is about one-third the way down the jar when cork is in place. Cut off surplus wire at other end, leaving about half an inch projecting from the glass tube.

Fix a small metal ball or plate on end of rod and let it drop down and rest on the end of glass tube.

Fig. 4. Gold Leaf Electroscope.

Hold ball up against tube and turn it upside down, pouring shellac varnish into the tube till it is filled. Give the cork a coat of shellac* also.

When dry the metal rod will be cemented in the tube and the tube into the cork.

Give outside of glass rod, the cork, the neck of bottle

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* A pure shellac varnish is meant, made by dissolving or "cutting," as it is called, flakes of gum shellac in alcohol. Wood or grain alcohol are equally good. Orange or brown shellac refer to the color of gum. Either will do.

inside and out two coats of shellac, allowing time for perfect drying between coats.

The cork will now be a good tight fit.

Scrape any shellac off the flattened end of the rod and paste on two strips of gold leaf, silver leaf, dutch metal or aluminum foil; as broad as the flat end itself is wide and long enough so as to just not hit the sides of the jar if they should stand out straight apart.

Cover the bottom of the jar an inch deep with *fresh* dry calcium chloride. Buy it the day you are going to put it in jar.

Give a last coat of shellac to the outside edge of the cork and putting it in jar press down firmly, seeing that the rod with its foil leaves hangs straight.

LESSON 2.

STATIC ELECTRICITY.

Question 1. What is static electricity?

Answer. I think it is a very small quantity of electricity at a very great pressure.

Question 2. Why do you think the quantity is small?

Answer. Because we cannot get any steady power out of static electricity.

Question 3. Lightning often does considerable damage. How do you account for that?

Answer. The damage done by lightning is like a blow or an explosion, and seems to be the result of great pressure.

Question 4. A static machine gives steady power, *i. e.*, a steady stream of sparks.

Answer. No, it doesn't. The sparks follow each other rapidly but are really intermittent. There is more time between sparks than the time of a single spark.

Question 5. Why do you think it has such a great pressure?

Answer. Because it will jump across distances which current electricity will not.

In all that we see of static electricity we are constantly reminded of the fact that it possesses a power to escape which enables it to cross a considerable space of one of the best insulators known—dry air. This must mean that static electricity is at a high pressure.

Question 6. Make this clearer.

Answer. A switch in an electric circuit can be almost closed and yet no current will pass till the switch is closed. Static electricity would have jumped across when the opening between the switch blades became small.

Question 7. Mention some easy ways of producing static electricity.

Answer. 1. If you will rub a fountain pen on your coat sleeve it will attract small pieces of paper.

2. A piece of glass rubbed with a silk necktie will do the same.

3. A spark will be produced by shuffling your feet along the carpet and then touching a gas jet. This is in miniature the same effect as lightning during a thunder shower.

Question 8. Are there still other ways to produce static electricity?

Answer. Yes. 1. *Friction* between two different substances will always produce electricity unless the dampness is excessive. A leather belt on a rotating pulley will become charged and give you a severe shock if you walk under it.

2. *Percussion.* A violent blow struck by one substance on another produces positive and negative charges.

3. *Breakage.* Tear a playing or a visiting card, or even a linen paper shipping tag suddenly across, and you will charge the two pieces. Crunching a lump of sugar quickly between the teeth does the same. Split a sheet of mica with a sudden motion and you will also charge the pieces.

Any of these tests done in a very dark room will show

faint sparks. The hard rubber slides of the plate holder of a camera, if pulled out suddenly on a dry day may make such a spark that you can hear the crackling noise above the sound made by the slide itself.

4. *Solidification.* When melted chocolate is poured into moulds, upon cooling and hardening it becomes electrified.

5. *Combustion.* The burning of a joss stick to keep away mosquitos causes it to become electrified.

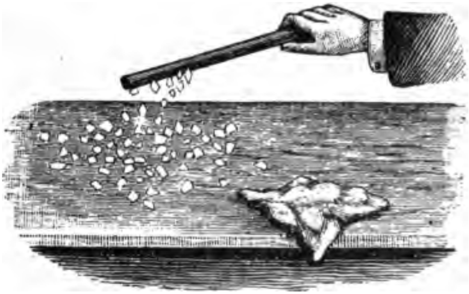

Fig. 5. Attraction due to Static Electricity.

6. *Evaporation.* The evaporation of a liquid from its surface, when that surface is roughened by waves, produces electrification. This is one of the ways that the atmosphere is kept charged relatively to the earth. In fair weather it is always positive to the earth and during rains and storms it is sometimes negative.

Question 9. Mention some other ways of showing static electricity.

Answer. Briskly rub a sheet of paper which is lying on a polished desk, with a rubber eraser, or even the hand. If the room is cool and dry the sheet will stick to the table.

If two sheets are laid down together and rubbed and both pulled away together; then when these are pulled apart they will forcibly repel each other.

Lay a glass rod on a table, one end of which extends over the edge a few inches. Attach to this a silk thread,* fastened to the lower end of which is a small ball of pith† from an elder or corn stalk.

Rub a second glass rod with a silk handkerchief and bring it near the pith ball. It will be strongly attracted, but almost immediately repelled, and it will not approach the glass rod again.

Now rub a stick of sealing wax or a piece of wood highly polished with shellac varnish, with a woolen rag or piece of flannel and bring this near the pith ball. It will be attracted and then repelled. We may repeat this attraction and repulsion as often as we please.

Question 10. I do not understand the repulsion. What causes it?

Answer. It is explained by saying that there are two kinds of static electricity or at least two states of it.

Question 11. Why does it seem that there are two kinds of static electricity?

Answer. The fact that under one set of circumstances an electrified body will be drawn to another body, and at other times will be repulsed by the same body, plainly indicates that there are two electrical states, one of attraction and the other of repulsion.

Question 12. Explain this further.

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* A single thread drawn from a piece of embroidery silk is best because it is very light and flexible.

† Any pith will do, and it may be purchased at a drug store.

Answer. The glass rod in *A9** attracted the pith ball and then repelled it. Since it acted differently towards the same charge of static electricity, there must have been a charge on the pith ball which had two conditions, one where it attracted and one where it repelled.

Question 13. How can these different states be produced or induced, as it is called?

Answer. Different electrical conditions are produced by different treatment of the bodies electrified. The glass rod rubbed by a silk handkerchief induced a condition which is unlike that induced by the flannel's friction on the sealing wax or shellac of the varnished wood.

Question 14. But this does not explain about the repulsion or the cause of it.

Answer. With the knowledge gained in this experiment and what we already know, we can find an explanation.

Lay two glass rods over the edge of the table and as far apart as possible and attach pith balls to each by silk threads.

To one present a glass rod rubbed with silk. It is first attracted and then repelled.

To the other present a stick of sealing wax that has been rubbed with flannel. It will be attracted and then repelled.

Take away the glass rod, the stick of wax, the silk and flannel to a distance. Pick up one of the glass rods and slowly bring its pith ball up towards the other. They will be attracted.

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*References to Answers in same Lesson will be made in this way.

Handle the pith balls with the fingers a few seconds to dissipate their charges. Replace them as before.

Rub the glass rod with silk and present to each pith ball. They will be attracted and repelled.

Now as before bring the pith balls together and they will repel each other.

Discharge the pith balls and repeat this last part, using the sealing wax rubbed with flannel.

The balls are attracted and repelled, and when brought near together they repel each other.

We already know from *A*9 that an unelectrified body is always attracted to an electric charge before being repelled.

From these demonstrated facts we deduce the following:

Similar electric charges repel each other. Dissimilar charges attract each other. Either electrical condition may show attraction for an unelectrified body.

In short:—

Like charges repel.

Unlike charges attract.

Charges attract neutral bodies.

Question 15. This explains why the two pith balls were first attracted when one was charged by glass rod and the other by sealing wax.

It explains why they repelled each other when both were charged by glass rods.

Explain why a neutral or unelectrified body is attracted and then repelled.

Answer. We have come to the conclusion that all bodies contain equal amounts of the two kinds of static electricity.

When a body rests undisturbed the opposite qualities of the parts neutralize each other and no outside effect is observed; indeed one is tempted to say that there is no electricity in the substance.

In a similar manner drinking a glassful of a solution of caustic soda or of diluted muriatic acid would corrode the lining of your stomach, and perhaps cause death.

Mixing the two would, if the chemicals were clean and pure, and present in the right quantities, produce a large glassful of a solution of table salt in water. I would have no fear in drinking this, except for the excessive thirst sure to follow such a salty beverage.

So the question is answered in this way:—

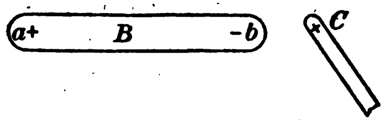

Fig. 6. State of a body B, having a charge induced in it due to the action of C.

An unelectrified pith ball is really only an uncharged one, for the two kinds of electricity are in it in equal quantities and neutralize each other.

When the glass rod charged with glass electricity was brought near the pith ball, the glass electricity of the glass rod repelled the glass electricity of the pith ball to the far side, and attracted the other kind (resinous) to the near side. See Fig. 6.

The attraction being nearer than the repulsion the whole pith ball with its separated electricities is pulled toward the glass rod.

When the pith ball gets very near the glass rod the

attraction of the glass electricity on the rod actually pulls the other kind (resinous) off the pith ball, leaving only the *glass* electricity. The glass rod now repels the pith ball even more strongly than it attracted it before.

When the stick of sealing wax was presented to a pith ball the same thing is done by the *resinous* electricity of the stick, it repels the resinous kind and attracts the glass kind. The same things occur and the ball is first attracted, then repelled.

Question 16. Are these names, glass and resinous, actually used?

Answer. Vitreous and *resinous* have been used, but these names are out of date and they are now known as *positive* and *negative* electricities.

The names are usually abbreviated by using the sign + for the positive, and — for the negative.

Question 17. Then an electric charge can induce a charge in another body, that is, cause its electricities to separate, without actually touching it?

Answer. Yes, as is shown in this experiment.

A sphere of metal, or wood covered with tinfoil is mounted on an insulating stand—a wooden stand with a glass rod for its support. A second similar stand has a horizontal cylinder of conducting material, or wood covered with foil, hanging from which are double threads of silk; and to these two or three inches below the cylinder are fastened little pith balls. See Fig. 30, on page 78.

These double threads, four or five in number, are distributed along the cylinder at regular intervals.

The little cylinder, say an inch in diameter and six inches long, is now insulated from the ground.

If the sphere is now charged and brought near one end of the cylinder, each pair of pith balls will show re-

pulsion and remain standing apart. Those at the two ends of the cylinder will show the greater repulsion and remain further apart than the pairs near its center.

If we now electrify a rubber comb or glass rod by rubbing it, we will see that, on approaching the pith balls, it will attract those at one end and repel those at the other; thus showing the ends of the cylinder to be oppositely electrified.

This proves conclusively that the approach of the charged sphere separated the two electrical conditions on the cylinders, attracting the opposite kind and repelling the same kind.

It also gives another proof that "Like charges repel," because each of the pith balls in a pair had the same kind of electricity in them, and repelled each other.

Question 18. Does the same charge always induce the same quantity of electricity?

Answer. Yes, as is shown in the following experiment.

As shown in Fig. 7, insulate a tin can by standing on a glass tumbler. Connect it to an electroscope.*

Charge a metal ball and lower into the can by a silk string, being careful not to let it touch the sides.

As the ball is lowered a charge is induced in the tin pail and the gold leaves of the electroscope diverge, showing it.

When the ball is well down into the pail the leaves will diverge no further, even if the ball is touched to the bottom.

This proves that the ball induced an *equal* and opposite

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* Turn back and read description of Electroscope.

charge in the pail because touching the pail with the ball added no more electricity.

Furthermore, after the ball has touched the pail pull it out and it will be found perfectly neutral.

It was neutralized by the *equal* and opposite charge which it induced.

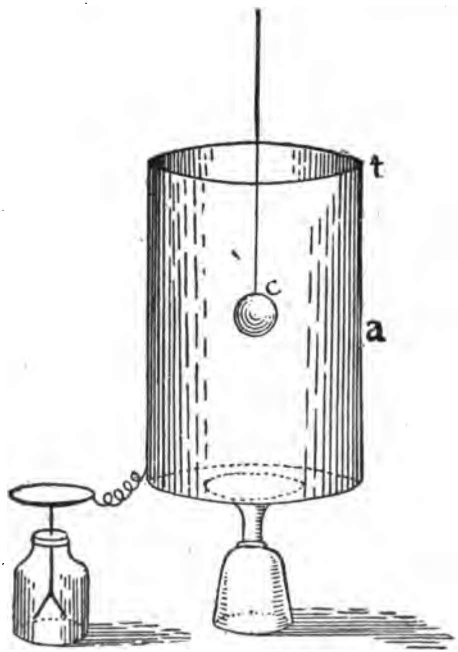

Fig. 7. Showing that the induced charge is equal and opposite to the inducing charge.

The electroscope was operated by the equal and like charge left free by the induction of the opposite charge.

Question 19. What is the usual trouble when experiments such as have been described won't work?

Answer. The things used are not perfectly dry or the air is too moist.

Question 20. What other things might cause trouble?

Answer. If the table used were set over a hot-air register, the current of hot air will carry away the electrical charges, perhaps as fast as produced.

LESSON 3.

STATIC ELECTRICITY (CONTINUED).

Question 1. Can you induce a + charge without at the same time inducing an equal — charge?

Answer. No.

Question 2. But when you rubbed the fountain pen, or the glass, or the carpet, as in *A7*, Lesson 2, only the pen, glass or body seemed to have charges.

Answer. Careful investigation will prove that the coat sleeve, necktie and the carpet under foot contain electrical charges as well as the pen, glass, and your body.

Question 3. Why *careful* investigation?

Answer. Because it is very easy to be deceived by appearances in any electrical test. Care must be taken that real effects are observed and to properly understand what we see.

Question 4. What test is usually applied to the coat sleeve, necktie and carpet to see if they are electrified, *i. e.,* if they contain a charge of static electricity?

Answer. A trial is made to see if they will attract pith balls or affect an electroscope.

Question 5. But they won't and therefore there is no charge on them.

Answer. No, not at the time they were tested, but while being rubbed or rubbing they were electrified.

Question 6. Where did the charge go?

Answer. To the ground. You see the pen and glass rod were insulators and insulated (Lesson 2) so that

the electrification produced by the friction remained on them, but the coat sleeve and silk necktie were not such good insulators and were grounded, so that the charge flowed away.

Question 7. But the glass rod and silk necktie were both held in the hands. How could one be insulated and the other not?

Answer. The glass rod being fairly long its lower part acts as an insulator for the upper part. The hand, which is a good conductor, makes a contact of small area with the lower end of the glass rod. Hence the charge on the other end, say three inches away, is insulated.

The necktie makes a contact of large area with the hand and the charge being on the other side of the silk, say a few thousandths of an inch away, is not properly insulated and leaks away.

Question 8. But the charge on your body when you drew a spark from the gas jet, did not flow away.

Answer. No; because the carpet was the better grounded of the two and, moreover, the charge in the carpet, while being rubbed, was actually there and repelled a charge into the body and held it there.

After the spark to the gas jet the charge in the carpet flowed away to the ground, and any excess charge on the body also flowed away to ground.

Question 9. How can you prove that the coat sleeve and necktie had charges while being rubbed?

Answer. By mounting a piece of woolen cloth to represent the coat sleeve on a glass rod and using this rod as a handle, rub the cloth on the fountain pen.

Both the cloth and the pen will become charged, as the charge on the cloth can not flow away, it remains, can be tested and proved to exist.

The same idea may be carried out with a scrap of silk and a glass rod.

Question 10. How do you test to prove a charge exists?

Answer. By using an electroscope.

Question 11. Describe an electroscope.

Answer. As shown in Fig. 4 and in Fig. 8, it consists of a glass jar sealed up, practically moisture proof, with two leaves of metal foil hanging from a metal rod in the jar, the other end of the metal rod in the air terminates in a metal ball.

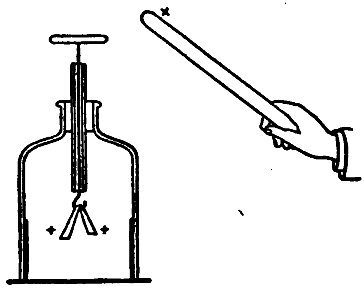

Fig. 8. Charging an Electroscope by Influence.

Two strips of foil are often pasted on the sides of the jar to discharge the foil leaves if they swing out too far.

Question 12. How do you prepare an electroscope for a test?

Answer. Rub a glass rod with a piece of silk and hold rod near the ball of the electroscope, but do not touch it. See Fig. 8. The leaves will diverge and remain apart.

While keeping the glass rod near the ball touch the ball with the other hand and remove hand. The leaves

fall together. Remove the glass rod to a distance and the leaves will diverge again.

Question 13. Why does the electroscope act this way while being charged?

Answer. When the charge of + electricity on the glass rod is held near the neutral electroscope it separates the electricities and attracts the — to the ball at the top and repels all the + to the leaves at the bottom of the metal rod.

The leaves being now both positively charged repel each other and diverge.

When the ball is touched with the finger the — electricity is held "bound" by the glass rod. Any + which would run in from the earth through the hand, is kept out by the + of the glass rod, while more — is attracted from the earth. This charge combines with the + in the leaves and neutralizes so that the leaves are no longer charged. They therefore stop repelling each other and fall together.

The — in the ball is still held "bound" by the + of the glass rod and can do nothing.

The finger being removed, and then the glass rod being taken away, the — charge which was in the ball spreads all over the ball, rod and leaves.

The leaves being now each charged with — they repel each other and diverge.

Notice that the final charge of the electroscope is opposite to the charge of the charging body.

Question 14. How do you test for a charge?

Answer. Bring the body on which a charge is suspected near the ball and if the leaves diverge further or fall together there is a charge on the body; if they are not affected there is no charge on the body.

Question 15. How do you determine the kind of electricity on the body?

Answer. If the leaves diverge further when a body is brought near the ball its charge is the same kind as is in the electroscope, if they come together it is charged with the opposite kind.

Question 16. What electricity is the electroscope usually charged with?

Answer. Usually a glass rod carrying a + charge is used, which induces a — charge in the electroscope.

Then a further divergence of the leaves means a — and a collapse of the leaves means a + charge on the tested body.

Question 17. What is the general rule for determining the kind of electricity with an electroscope?

Answer. Collapse of leaves means same kind of electricity as was used to charge the electroscope. Divergence of leaves means different kind.

Question 18. How can you charge any body so as to have only one kind of electricity in it?

Answer. By inducing a separation of the electricities by means of a charged body and then drawing off the "free" charge by touching the body with the finger.

Question 19. What does *bound* and *free* charges mean?

Answer. A *bound* charge means a charge which is attracted and held by a charge of the opposite kind.

Touching a body with a bound charge has no effect upon it, because it is not free to neutralize with any electricity that might flow in, nor can it flow away, since it is held by the other charge.

A *free* charge is a charge which is under no influence or under the influence of a charge of the same kind.

When a body is touched the free charge is either neutralized by the inflowing charge or flows away itself to the earth. Probably both of these actions take place.

Question 20. What is the best way to get a fairly large charge of electricity?

Answer. By the Electrophorous.

Question 21. Describe the Electrophorous.

Answer. As shown in Figs. 1 and 9 it consists of a plate of resin resting on a metal plate, and a second metal plate with an insulated handle, rests on the resin.

Fig. 9. Using an electrophorous.

Question 22. How is the Electrophorous used?

Answer. The upper plate or cover is removed and the cake of resin is rubbed or beaten with a piece of warm dry flannel or cat's skin.

The cover is then taken up by the glass handle and placed lightly on the cake. With thumb and forefinger touch the metal plate containing the resin cake and the metal cover at the same time.

Lift the cover off by the handle and it will be charged.

Question 23. How can you prove it?

Answer. By drawing a spark from it by the finger.

Question 24. Do you rub the resin cake each time you want a spark?

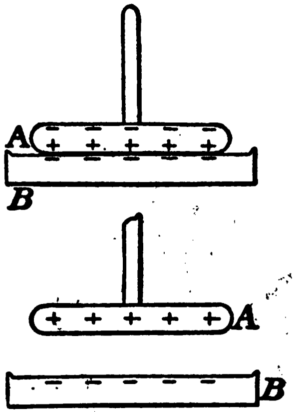

Fig. 10. The Electrical State of an Electrophorous when cover is on, and then after being touched and cover lifted.

Answer. No. The cover may be replaced, touched as before, removed, and a spark drawn, over and over again. If left after being used the charge on the cake will leak away and rubbing will be necessary.

Question 25. Explain how the Electrophorous works.

Answer. When the resinous cake is first beaten its surface is —ly electrified and the + driven into the metal pan. See Fig. 10. When the metal cover is placed lightly on the cake it does not touch at all points and is really an insulated conductor.

The — charge on the resin cake acts by influence on the cover and induces a + charge on its under side and repels the — charge to the upper side.

When the cover and the bottom pan are touched by the finger, several things happen. From the earth the resin cake attracts more + charge to the lower side of the cover and repels the — on the upper side of cover out to the earth through the finger. This gives the cover a larger + charge than before. This + charge is bound and cannot escape.

The connection of the bottom pan to earth allows its + charge to be increased, which in turn helps to "bind" the — charge on the resin.

If the cover is now lifted by the insulated handle the + charge on it spreads over it and it is charged ready to give a spark.

Question 26. Will the Electrophorous work if only the cover is touched with the finger?

Answer. Yes, but the spark is stronger when both cover and pan are touched.

Question 27. Is the original charge used up in drawing several sparks in succession?

Answer. No, because the electricity which gives the spark is really drawn from the earth each time.

Question 28. You have obtained energy without any cost, have you not? This is contrary to nature's laws.

Answer. No. The cost of the spark is the muscular effort of the first rubbing, and the subsequent touching and liftings.

Question 29. How can a larger charge be obtained?

Answer. By accumulating the small charges given by the electrophorous.

Question 30. What is used to accumulate charges?

Answer. A Leyden Jar.

Question 31. What is a Leyden Jar?

Answer. It is a glass jar lined inside and outside with

tinfoil with a conductor passing through an insulated cork touching the inside foil. See Fig. 2.

Question 32. How is the Leyden jar used?

Answer. To get the best results connect the outer coating of tinfoil with a wire or chain to a gas or water pipe, thus giving a good connection with the earth.

When the cover of the electrophorous is lifted, present it to the knob of the jar and let the spark jump to it. Repeat this a dozen times, and the jar will be charged.

Question 33. How do you show this charge?

Answer. Connect the ball with the outer coating using the discharger (Fig. 3) and a heavy spark will be obtained.

Question 34. Will it be twelve times as large as the electrophorous spark?

Answer. No. It will be much larger than the electrophorous spark, but not twelve times as large, for there are leaks and other losses which will reduce its size.

Question 35. Explain the main leak.

Answer. Glass is a hygroscopic substance. This means that moisture collects on its surface very easily. A china tea cup will have a dry surface in a room, while a glass tumbler alongside of it will have a very damp surface.

The charge leaks from one coating of tin foil to the other over this film of moisture.

The shellac varnish on the glass is to prevent this film of moisture forming. It does this very well.

Question 36. What is another cause of leakage?

Answer. There is the leakage from the coatings to the air, because particles of air become electrified and are then repelled.

Question 37. Why does not all the charge leak away?

Answer. In a poorly made jar it will; but with well shellaced glass, used in a dry atmosphere the leakage is slow, and the binding influence of the inner and outer charges on each other retains the charge.

Question 38. Is there any other leakage?

Answer. Yes there is leakage through the glass. While glass is principally sand and soda yet there are other ingredients added according to the grade of glass. The cheaper kinds have accidental ingredients, really impurities, which lessen its value for electrical purposes. A general rule is that the more expensive the glass the better for electrical work.

A leyden jar to approach nearest to electrical perfection should be of glass containing no lead or other conducting material.

For simple experimenting a cheap glass such as bottles or fruit jars are made of will do.

In such cases it is absolutely necessary to coat the glass with shellac varnish before putting on the tin foil.

Question 39. How can a larger spark be obtained?

Answer. By accumulating more electrophorous sparks.

Question 40. Is there any limit to the size?

Answer. Yes; in time the pressure of the charge to escape will be so great that the charge will either leak as fast as it is added to or the pressure will flash a spark over the edge of the glass.

Question 41. Will a larger leyden jar give a larger spark?

Answer. Yes, a jar large enough to have twice the amount of tin foil put on will give twice as large a spark.

Question 42. What do you mean by "twice as large a spark?"

Answer. Either twice as long a spark, the same length but twice as thick or some combination like this. Twice as long and twice as thick, would be a spark four times as large.

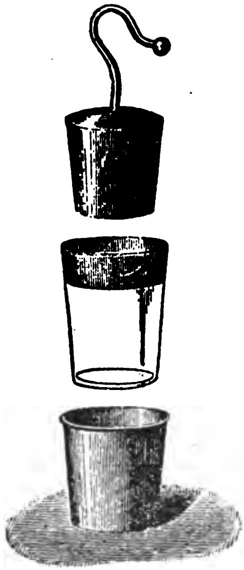

Fig. 11. A Leyden Jar with Removable Coatings.

Question 43. Can several leyden jars be used at once?

Answer. Yes, stand them all on a sheet of metal, and connect all the knobs together with a piece of wire. This is now the same as one big jar. Fig. 27, page 75.

Question 44. How does a leyden jar work?

Answer. The theory of the leyden jar is best explained through the aid of an experiment, which requires a peculiar form of jar, but which is easily constructed.

Take a large glass tumbler, and varnish inside and out with shellac. Arrange the inner and outer coatings so as to be removable. Fig. 11 shows one where the coatings have been made thick and stiff to facilitate their removal.

A jar may be arranged more simply by attaching a ball of tin foil refuse to the lower end of the rod so that it will rest on the bottom of the jar and form the inner coating.

For the outer coating thin sheet metal or foil may be wrapped around the jar and tied with thread.

Place a board on several glass tumblers thus making an insulated stand. Place jar on stand.

Charge the jar. Lift out the rod and inner coating—being careful not to come within sparking distance of the outer coating—and place on board. Now lift the jar from the outer coating and place on board.

In each of these contacts a very slight shock will be received by the hand.

A test of the two coatings will show that they are neutral, as is natural since any charge on them would be neutralized by touching them by the hand.

Replace the jar in its coating, and put the inner coating in place. Discharge the jar by making contact between the coatings, and it will be seen that there is nearly as much electricity in the jar now as if the coatings had not been disturbed.

It is evident then that when the inner and outer coatings were removed that the electricity in the jar was not disturbed, for the outer charge remained bound after the inner coating was removed.

We explain this by saying that the charges are really

on the inner and outer surfaces of the glass and that the tin foil is only a means of getting the charge to the glass.

When we took the jar apart the slight shocks were due to leaks, but the main charges stayed on the glass.

Question 45. Could the glass be discharged while out of its coatings?

Answer. Yes, by connecting inside and outside by a broad strip of tin foil. Doing this as if you were trying to wipe off the charge.

Holding the glass under a tap and running water over it will instantly discharge it.

Question 46. Will you get a spark by this discharge?

Answer. It depends. If you make a broad contact at first you will not, because the charge flows over such a large surface. If you get a spark it is a feeble one for the glass being an insulator it cannot rush to the point of discharge quickly enough to make a heavy spark.

Question 47. Do the foil coatings enable a spark to be obtained?

Answer. Yes, without them the discharge is a fast leak; with them the charge can rush through the conducting coatings to the discharging tongs and the discharge is a quick snappy one.

Question 48. Why will a leyden jar give a second spark a few seconds after being discharged?

Answer. We believe that the charges penetrate the glass to a certain extent and the first spark discharges all the charge on the surface of the glass, but it is over before the charge which soaked into the glass has time to escape.

The second time the jar is discharged we allow this residual charge, which has come back to the surface, a

chance to escape. This second spark is very much weaker than the first one.

Question 49. What is meant by saying that the discharge of a leyden jar is *oscillatory?*

Answer. In the first place the spark or discharge is not instantaneous although very quick. This can be shown by flashing a spark at some gunpowder, it will not explode, but insert a piece of wet string about a foot long in the wire leading up to the spark gap and the spark will be forced to travel slower. It will then in its slower movement heat up the gunpowder and ignite it.

But this is not all. The spark as we call it, whether it be a fast or slow one, is not a single spark, but a series of sparks.

There are always a great number of them jumping in alternate directions, each weaker than the last until they are too feeble to jump across the gap. The electricity which forms the spark *surges* or *oscillates* between the sparking points.

The sudden emptying of a barrel of water in a tank will cause the water in tank to surge back and forth, in waves, each successive one being smaller, until the whole mass settles down and becomes quiet.

The action of a pendulum set in motion and gradually coming to rest illustrates the action also, provided you imagine the pendulum moving at a furious speed,

LESSON 4.

CONDENSERS.

Question 1. Why is a leyden jar often referred to as a condenser?

Answer. Because that is the general name for apparatus designed to collect charges of electricity.

Question 2. What is a condenser?

Answer. A condenser consists of two metal plates separated by an insulator.

Question 3. What is the *dielectric* of a condenser?

Answer. It is the special name given to the insulator of a condenser.

Question 4. Explain the action of a condenser.

Answer. If a pane of glass be set on edge and a piece of tin foil pasted on one side it will have a certain capacity for electricity, but if another piece is pasted on the other side and charged with the opposite kind of electricity then the first piece will have a greater capacity. It is as if this arrangement could condense electricity, that is get more in the same space.

Question 5. What is meant by capacity?

Answer. A piece of tin foil could have its charge increased until the leakage equalled the amount put on, then we might say that it was full, and that the amount on it was its capacity. Since this amount would vary with the dampness of the air, the temperature of the tin foil, and the rate at which you added electricity, a more definite way has been adopted to define *Capacity*.

A certain pressure is called a volt. We apply electricity to the condenser increasing the pressure until it becomes one volt, then we say the condenser is full enough and the charge then in it is said to be the *capacity* of the condenser.

Question 6. On what does the capacity of a condenser depend?

Answer. On three things:—

1. The area of the metal part.
2. The thinness of the dielectric.
3. The kind of dielectric.

Question 7. Does not the kind of metal used or its thickness affect the capacity?

Answer. No, only the area. The greater the area the greater the capacity.

Question 8. Why is it that the thinness of the dielectric affects the capacity?

Answer. Because the thinner the dielectric the nearer the metal portions are to each other and so the electrical action between the charges is greater.

Question 9. Why should the material used as a dielectric affect the capacity?

Answer. Exactly why is not known, but it is a fact that the electric action takes place through the same thickness of different materials with more or less strength according to the material.

Question 10. What is the metal portion of a condenser usually made of?

Answer. It is always made of tin foil, for it is thin and hence light in weight for large areas.

Question 11. What is used generally as a dielectric?

Answer. For condensers used in commercial work, paper soaked in paraffin is used while for standard con-

densers used in laboratories to test others, mica split into thin sheets is used.

Question 12. What are the advantages of the paper condensers, as they are called?

Answer. They are cheap to make, light in weight and good enough for many purposes.

Question 13. What are the objections to paper condensers?

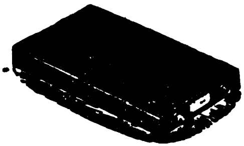

Fig. 12. Paper Condenser.

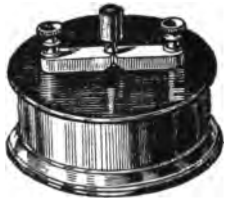

Fig. 13. Mica Condenser.

Answer. They cannot hold a charge as long as a mica condenser, as the insulation is not so good. They leak considerably, that is the charge leaks from foil to foil, thus discharging the condenser. If rapidly charged and discharged the paraffin is heated and may soften or even melt.

Question 14. What are the advantages of the mica condensers?

Answer. They hold their charge without leaking for a long time, rapid charge and discharge does not heat them much, and even so mica is not affected by temperatures at which paraffin would liquefy. Their capacity is great, so a mica condenser is smaller than a paper one of the same capacity.

Question 15. What are the objections to mica condensers?

Answer. They are expensive, and while small in size are very heavy.

Question 16. How would the capacities of three similar condensers of mica, paraffined paper, and glass compare?

Answer. Selecting a condenser with air for a dielectric as a standard because it is the poorest condenser of all, the mica is the best being six to eight times as good as the air condenser. The glass one would be three times as good as the air one. The paraffined paper dielectric makes the poorest condenser being only twice as good as air.

It must be remembered that some mica, such as used in oil and gas stoves is worthless as a dielectric, as it has fine lines of metal running through it, and hence is a conductor.

Some grades of glass are also almost useless for a condenser.

Question 17. What is the standard capacity?

Answer. The scientists' standard was a metal sphere of 1 cm * radius perfectly isolated and insulated.

This capacity is so absurdly large that all electricians used as a standard a unit which is 1-900000 of the other.

This unit is called a microfarad (abbreviated *m. f.*) and is now used by scientists and electricians.

Question 18. How big a condenser is a microfarad?

Answer. A mica condenser containing 3600 square inches of tin foil.

Question 19. How is a paper condenser made?

---

* The centimeter (abbreviated *cm.*) is the 1/100 part of the French standard length called the meter. A meter is approximately 39.3 inches, so a centimeter is about 0.4 inches and there are roughly 2½ cm. to one inch.

Answer. The finest and thinnest linen paper is examined to be sure that it is free from small holes, the tiniest hole causes a sheet to be rejected.

They are then dried and warmed, dipped in a bath of melted paraffin, from which all water has been extracted, and allowed to drain and cool.

A pile is made of alternate sheets of tin foil and paper. The papers are placed with all their edges even, but each alternate foil projects on the same side of the pile. The first, third, fifth foils project to the right and all the even numbered foils project to the left.

Each set are all connected together, and the whole mass clamped tightly and put in a case for protection.

Binding posts are connected to each set of foils.

Question 20. What name is given to the quality of a dielectric?

Answer. Dielectric capacity or *specific inductive capacity* is the name used.

Question 21. What is the standard of dielectric capacity?

Answer. Perfectly dry air at normal pressure and temperature of 0° Centigrade* is said to have a dielectric capacity of 1.

Question 22. How is the dielectric capacity of materials measured?

Answer. By comparing them with air. Air has the least value as a dielectric, so other materials are said to

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* The Fahrenheit thermometer is the standard throughout the business and social life of the United States and Great Britain.

The temperature of freezing water is called 32 degrees and that of boiling water 212 degrees. The range between these temperatures is divided into 180 equal parts, numbered consecutively from 33 to 211, and as far below 32 and above 212

as is needed these equal divisions are carried. If carried below 0, we read the temperatures as minus 1, minus 2, or 1 below zero, 2 below zero; and we write them —1, —2.

In scientific work all over the world, the thermometers are marked differently.

The freezing point of water is marked 0 and the boiling point of water 100, and the space between into 100 equal parts. These divisions are carried down below the zero and above the 100 mark.

This thermometer was introduced by a man named Celcius, but is named Centigrade because it has 100 steps between freezing and boiling points. (Centum is 100 in Latin and gradus means step.)

Since 100° Cent. = 212° Fah.
and 0° Cent. = 32° Fah.
then 100° Cent. = 180° Fah.
and 1 Cent. degree = 1.8 Fah. degree.

To change Centigrade readings to Fahrenheit:

Multiply by 1.8 and add 32.

Ex.—A room whose temperature is 21° C. is 69°.2 Fah.

$21 \times 1.8 = 37.2 + 32 = 69.2.$

To change from Fahrenheit to Centigrade:

Subtract 32. Multiply by 5 and divide by 9.

A room which is 70° Fah. is also 21° (approx.) Cent.

$70 - 32 = 38$

$38 \times 5 = 190 \qquad 190 \div 9 = 21°.1$ Cent.

The mark ° means degree and the abbreviation C. or Fah. after it tells the kind of degree.

When a decimal fraction is written it is always thus: 7°.2, so that should the decimal point be forgotten or not written clearly it can not be mistaken for 72°.

Also when a fraction of a degree is written it is thus: 0°.5, so that we may know that it is five-tenths of a degree and not 5 degrees even if decimal point is not there.

The 0 is placed there to show that it really is five-tenths and that some figure has not been forgotten.

It might be that 2°.5 was meant and °.5 written by an omission. By writing 0°.5 the writer shows he has not forgotten a figure.

have a dielectric capacity of 2 or 3 as the case may be, if they are twice or three times as good as air, when used in a condenser.

Question 23. Has capacity any effect on commercial work?

Answer. Yes a great deal.

Question 24. Mention some effects.

Answer. In sending alternating currents through a long line the presence of capacity may help to neutralize some of the bad effects of coils of wire in the circuit.*

Also in telephone lines the presence of much capacity is exceedingly bad, making the transmission of the voice difficult and producing a tinny tone.

For this reason paper insulation is used in telephone cables, rather than rubber. The latter has a much higher dielectric capacity, making the cable a better condenser and a worse telephone line.

Question 25. Are there any other effects?

Answer. Yes. The capacity of long telegraph lines makes signalling very slow; for the line has to be filled up each time before the signal will be transmitted, and it has to empty itself before the next signal can begin.

Long submarine cables are especially troubled this way. The wire inside and the water outside are the two conductors and the gutta percha† insulation is the dielectric. This makes a condenser.

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* A *circuit* is the path of the current from the battery or generator out and back again to the starting point. By ***line*** we often mean the same thing.

† Gutta percha is a gum something like rubber but a better insulator, less dielectric capacity, less likely to deteriorate with age, and can stand more moisture. It is injured by **light**, and should never be used in a light, hot, dry place. **It is**

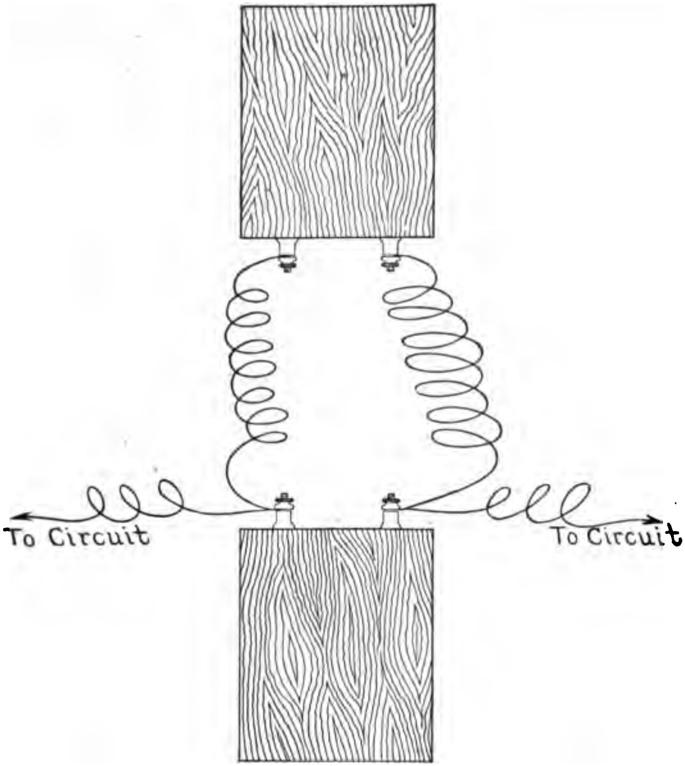

Fig. 14. **Two Condensers wired so as to be in Parallel.**

One of the Atlantic cables has a capacity of about 1000 m. f. (microfarads). This makes the signalling very slow and limits the amount of business that can be transacted per hour.

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easily softened by placing in hot water. It is lighter than rubber and a piece of it will usually float.

It is used chiefly as an insulator in ocean cables.

The operators can send faster than the cable can take; that is if the operators went as fast as they could, the signals would jumble up and be unintelligible at receiving end.

Question 26. How are condensers used in commercial work?

Answer. In ocean cable telegraphy a condenser is often put in at each end, which by absorbing the electricity on the opening of the circuit and giving it out on the closing of the circuit, help the battery to fill the cable on the close of the telegraph key, and help to stop the electrical flow when key is opened.

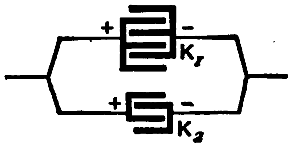

Fig. 15. Diagram of Two Condensers connected in Parallel. The black lines represent the sheets of tin foil.

In ordinary telegraphy when sending two or four messages over the same wire at the same time, an artificial line must be formed which is electrically exactly like the real line. Coils of wire give the resistance of the actual line, and condensers its capacity.

Question 27. How can two condensers be used as one large condenser?

Answer. As in Fig. 14, connect a wire from one binding post of the first condenser to either binding post of the other condenser. Connect the other two posts by a wire. Connect the wires of the circuit, one to each of the wires joining the condensers.

A convenient way of attaching the wires of the circuit is to loosen up both binding posts on the one condenser; slip the circuit wires under and tighten up again.

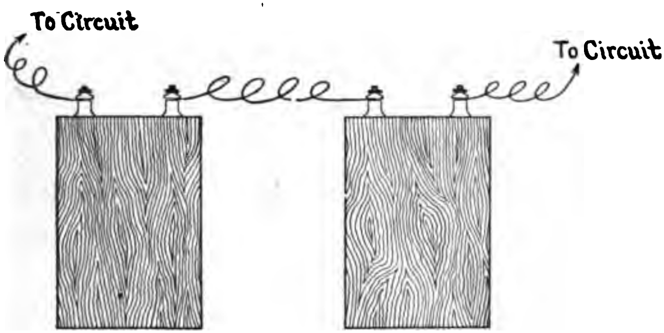

Fig. 16. Two Condensers in Series.

Question 28. What is the actual capacity of two condensers connected in parallel?

Answer. The capacity of this arrangement is the *sum of the two capacities.*

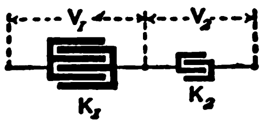

Fig. 17. Diagram of Two Condensers in Series. K_1 is supposed to have a greater capacity than K_2. The dotted lines show where to connect voltmeters V_1 & V_2 to read pressure of condensers.

Question 29. Suppose you connect the circuit (or line) through the two condensers?

Answer. If as shown in Fig. 16 you bring a line wire to one binding post of the first condenser, and the other

line wire to a post of the other condenser, and join the other two posts with a wire you will have them in series.

Question 30. What is the capacity of two condensers in series?

Answer. The actual capacity of the two in series will be *the product of the two divided by their sum.*

Calling C_1 and C_2 the capacities of the condensers, the joint or combined capacity will be expressed as $\frac{C_1 \times C_2}{C_1 + C_2}$

Ex.:—A 2 m f and a 3 m f condenser are connected in series. What is capacity of combination?

$$\frac{C_1 \times C_2}{C_1 + C_2} = \frac{2 \times 3}{2+3} = \frac{6}{5} = 1.2 \text{ m f.}$$

You will notice that the capacity of the two wired up in this way is less than the capacity of either.

Question 31. Suppose you connect three condensers or even more in parallel. What is their joint capacity?

Answer. The sum of their separate capacities.

Question 32. Suppose you connect three or more condensers in series, or as it is sometimes called in *cascade.* What is their joint capacity?

Answer. Divide each separate capacity into 1 add the answers and divide this into 1. Result is joint capacity.

Suppose three condensers have capacities of ½, 3 and 5 mf.

$\frac{1}{2}$ into 1 goes 2 equals $\frac{30}{15}$

3 into 1 goes $\frac{1}{3}$ equals $\frac{5}{15}$

5 into 1 goes $\frac{1}{5}$ equals $\frac{3}{15}$

Sum $\frac{38}{15}$

$\frac{38}{15}$ into 1 goes $\frac{15}{38}$ times.

$\frac{15}{38}$ or 0.4 (approx) m f.

Question 33. Describe an experiment showing how a condenser works.

Answer. Suppose as in Fig. 18 we have two metal disks A and B insulated by glass supports, with a sheet of glass or mica between them.

Let B be connected by a wire to the knob of an electric machine and let A be joined to a gas or water pipe by a wire; thus connecting it to ground or earth.

The + charge from machine will act by induction across the dielectric C, on A and repel + to earth, leaving the disk A — ly charged.

This — charge will react on B and draw more + from the machine.

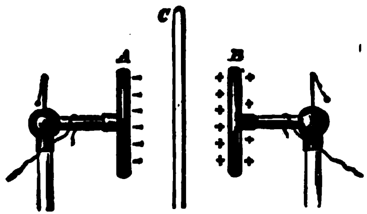

Fig. 18. A Condenser arranged so as to use different dielectrics at C, and with plates A & B movable.

The nearer A and B are together the better the induction acts and the more electricity will be condensed.

If the wires be removed from A and B and the disks drawn apart, the pith balls will fly out showing that there is more electricity "free" to act than before.

We ought not to say more electricity is present, it is simply more "free"; for the two charges will not hold each other so "bound" at the greater distance. This freed electricity spreads over the plate and balls. When the disks approach each other again this free electricity is drawn back to the plates and held bound. Hence the pith balls become discharged or nearly so and fall.

LESSON 5.

Electrical Machines.

Question 1. What is an electrical machine?

Answer. Used in this sense the words mean any of the machines capable of producing static electricity.

Question 2. Describe the simplest machine.

Answer. The simplest machine is a friction machine. A circular glass plate is mounted on an axle and arranged so as to be turned rapidly by belt and pulley. See Fig. 19.

At the top and bottom of plate a cushion of curled hair covered with leather is bent around so as to squeeze the plate. Light springs keep these cushions in firm contact.

At both sides of the plate is a set of spikes nearly touching the plate both on the back and the front. A conductor connects the two sets of spikes. A wire from this conductor leads to a metal knob or club which is called the prime conductor.

The two cushions are connected by a wire, and this in turn to the ground.

A silk bag or flap runs from the cushion or rubber to the spikes or comb. Both the rubber and the comb are insulated by glass supports.

The rubber has a thin layer of tallow spread on it and some powdered electrical amalgam sprinkled on. They are then pressed against the glass and the springs adjusted to keep them there.

When the plate is rapidly revolved the friction between the glass and the amalgam coated surface of the rubber

produces electrification; a + charge on the glass and a — charge on the rubber.

Positive electricity flows from earth to the rubber and neutralizes its charge. In fact the ground wire keeps the rubber continually neutral.

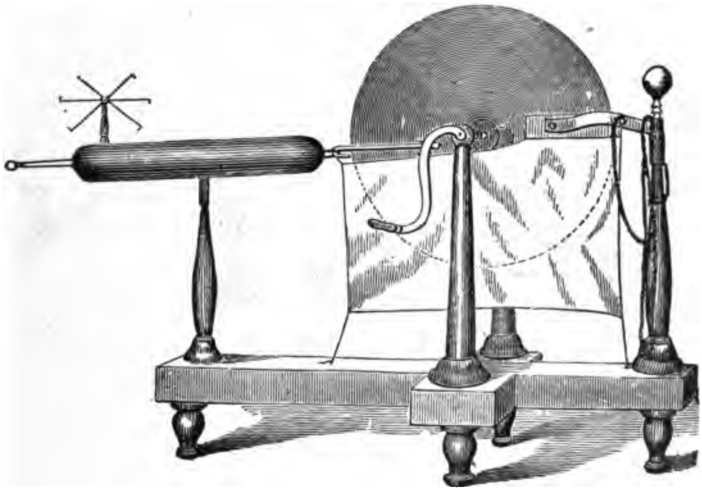

Fig. 19. Simple Electrical Machine.

The + charge is carried around on the glass in front of the comb which is connected with the prime conductor repelling a + charge to the knob of the conductor and attracting the — into the comb. The effect of the spikes is to emit a —ly charged electrical wind which neutralizes the glass plate and prepares it for the action of the next rubber and at the same time leaves the prime conductor +ly charged.

Question 3. What is electrical amalgam?

Answer. One ounce of tin and one ounce of zinc are

melted together and while melted four ounces of mercury are stirred in. When cool the mass is powdered and sifted. It may be sprinkled on the rubber from a salt shaker.

Question 4. Why is this amalgam used?

Answer. It produces a better charge than any other substance and moreover, by being a conductor helps the prompt neutralization of the rubber, which also tends to make the charge on the glass plate larger.

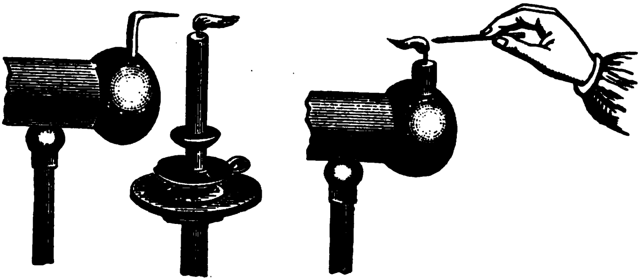

Fig. 20. Electrical Winds.

Question 5. Is the use of this amalgam necessary?

Answer. No. Powdered graphite will work very well. Simply rub it into the leather of the cushion. Of course omit the tallowing.

Question 6. What is an electrical wind?

Answer. It has been found that electricity leaks from sharp cornered bodies like a cube faster than from rounded ones like a ball. From sharp pointed bodies it leaks so fast as to actually produce a brisk air current.

If a needle be fastened to the prime conductor and a lighted candle held near the needle the wind rushing off the needle will blow the candle flame aside. See Fig. 20.

The wind can also be plainly felt by the hand.

Question 7. Why does the candle on the knob get blown in the opposite direction?

Answer. Because now the wind is caused by the opposite kind of electricity flowing off the needle to the knob.

The wind is always blowing off the point.

Question 8. What are the silk bags for?

Answer. The silk being an insulator prevents the + charge on the glass from leaking off into the air before it arrives at the comb.

It is believed by many that the air currents produced by the swiftly moving plate, electrifying the silk negatively and being a non-conductor, it is imperfectly neutralized by any ground connection that may happen to exist, so there is always a — charge on the silk to "bind" the + charge on the glass.

This action is not strong enough to interfere with the effect of the negative wind at the comb.

Question 9. Are not frictional machines generally unreliable?

Answer. Yes. Dampness and dust may prevent them from working. Glass attracts moisture so that the machines always have to be heated to dry them before use.

The amalgam will need renewing before use if the machine has been standing idle for a couple of months.

Question 10. Is there another type of electrical machine more reliable?

Answer. Yes, the influence machine. These are very reliable.

Question 11. What principle do they involve?

Answer. The principle of charging induction or influence, and of doubling up charges.

Question 12. Explain what is meant by charging by influence?

Answer. A body touched while under the influence of a charge acquires a charge of the opposite kind.

Question 13. What is meant by doubling up charge?

Answer. Suppose one (A) of two insulated conductors (A and B) is charged ever so little with say + electricity. Let a third insulated conductor, which we will call a *carrier* be arranged so as to move back and forth between A and B.

Let C be touched with finger while near A.

It will acquire a small — charge. Move it over and make contact with B which will receive some — electricity. Move C a short distance from B and touch it. C will acquire a + charge by influence.

Move C over to A and let them make contact which will give some more + electricity to A. Move C away a short distance and touch it. This charges C with — electricity. Move C over to B and make contact which increases the — charge on B.

Keep this up and the charges on A and B keep increasing and by acting more strongly on C they make the increase a rapid one.

Question 14. What machines work on these principles?

Answer. The Toepler machine which has been perfected by Holtz and Voss, and the Wimshurst machine.

Question 15. Describe the Toepler machine.

Answer. The principle of the machine is described by Silvanus Thompson.

Before describing some special forms we will deal with a generalized type of machine having two fixed field-

plates, A and B, which are to become respectively + and —, and a set of carriers, attached to a rotating disk or armature. Figure 21 gives in a diagrammatic way a view of the essential parts. For convenience of drawing it is shown as if the metal field-plates A and B were affixed to the outside of an outer stationary cylinder of glass;

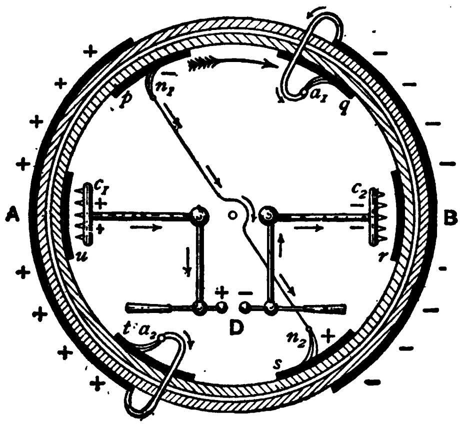

Fig. 21. Diagram to show the principles upon which the Toepler Machine operates.

the six carriers p, q, r, s, t, and u being attached to the inside of an inner rotating cylinder. The essential parts then are as follows:

(I) A pair of field-plates A and B.

(II) A set of rotating carriers p, q, r, s, t, and u.

(III) A pair of neutralizing brushes n_1, n_2 made of flexible metal wires, the function of which is to touch the carriers while they are under the influence of the field-plates. They are connected together by a diagonal conductor, which need not be insulated.

(IV) A pair of appropriating brushes a_1, a_2, which reach over from the field-plates to appropriate the charges that are conveyed around by the carriers, and impart them to the field-plates.

(V) In addition to the above, which are sufficient to constitute a complete self-exciting machine, it is usual to add a discharging apparatus, consisting of two combs c_1, c_2, to collect any unappropriated charges from the carriers after they have passed the appropriating brushes; these combs being connected to the adjustable discharging balls at D.

The operation of the machine is as follows. The neutralizing brushes are set so as to touch the moving carriers just before they pass out of the influence of the field-plates. Suppose the field-plate A to be charged ever so little positively, then the carrier p, touched by n, just as it passes, will acquire a slight negative charge, which it will convey forward to the appropriating brush a_1, and will thus make B slightly negative. Each of the carriers as it passes to the right over the top will do the same thing. Similarly each of the carriers as it passes from right to left at the lower side will be touched by n_2 while under the influence of the — charge on B, and will convey a small + charge to A through the appropriating brush a_2. In this way A will rapidly become more and more +, and B more and more —; and the more highly charged they become, the more do the collecting combs c_1 and c_2 receive of unappropriated charges. Sparks will snap across between the discharging knobs at D.

The machine will not be self-exciting unless there is a good metallic contact made by the neutralizing brushes and by the appropriating brushes. If the discharging apparatus were fitted at c_1, c_2 with contact brushes instead of spiked combs, the machine would be liable to lose the charge of the field-plates, or even to have their charges reversed in sign whenever a large spark was taken from the knobs.

It will be noticed that there are two thicknesses of glass between the fixed field-plates and the rotating carriers. The glass serves not only to hold the metal parts, but prevents the possibility of back-discharges (by sparks or winds) from the carriers to the field-plates as they pass.

Toepler's Influence Machine.—In this machine, as constructed by Voss, are embodied various points due to Holtz and others. Its construction follows almost literally the diagram already explained, but instead of having two cylinders, one inside the other, it has two flat disks of varnished glass, one fixed, the other slightly smaller rotating in front of it (Fig. 22). The field-plates A and B consist of pieces of tinfoil, cemented on the back of the back disk, each protected by a coating of varnished paper. The carriers are small disks or sectors of tinfoil, to the number of six or eight, cemented to the front of the front disk. To prevent them from being worn away by rubbing against the brushes a small metallic button is attached to the middle of each. The neutralizing brushes n_1, n_2 are small whisps of fine springy brass wire, and are mounted on the ends of a diagonal conductor Z. The appropriating brushes a_1, a_2 are also of thin brass wire, and are fastened to clamps projecting from the edge of the fixed disk, so that they communicate metallically with the two

field-plates. The collecting combs, which have brass-spikes so short as not to touch the carriers, are mounted on insulating pillars and are connected to the adjustable discharging knobs D_1, D_2. These also communicate with

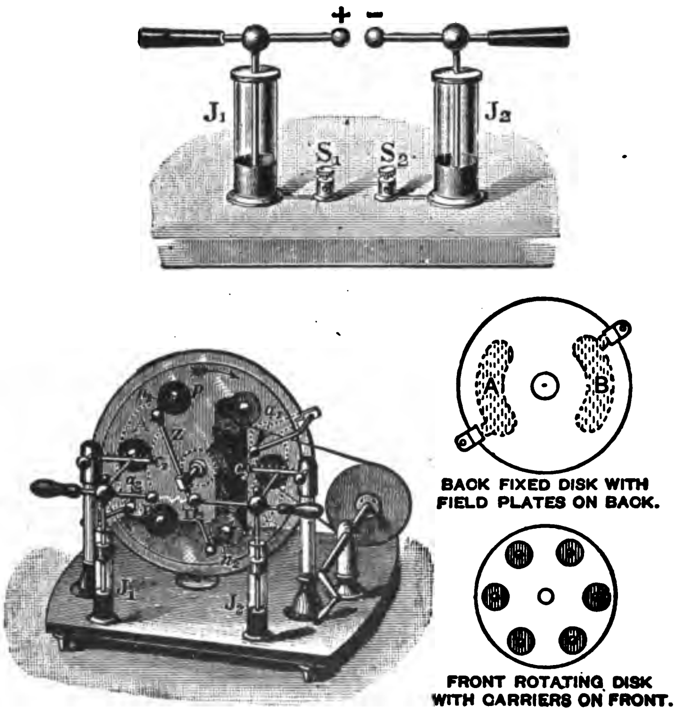

Fig. 22. A Toepler Electrical Machine.

the two small Leyden jars J_1, J_2, the function of which is to accumulate the charges before any discharge takes place. These jars are separately depicted in Fig. 22. Without them, the discharges between the knobs take

place in frequent thin blue sparks. With them the sparks are less numerous, but more brilliant and noisy.

To use the Toepler (Voss) machine first see that all the four brushes are so set as to make good metallic contact with the carriers as they move past, and that the neutralizing brushes are set so as to touch the carriers while under influence. Then see that the discharging knobs are drawn widely apart. If it is clean it should excite itself after a couple of turns, and will emit a gentle hissing sound, due to internal discharges (visible as blue glimmers in the dark), and will offer more resistance to turning. If then the knobs are pushed nearer together sparks will pass across between them. The jars (the addition of which we owe to Holtz) should be kept free from dust. Sometimes a pair of terminal screws are added at S_1, S_2 (Fig. 22) connected respectively with the outer coatings of the jars. These are convenient for attaching wires to lead away discharges for experiments at a distance. If not so used they should be joined together by a short wire, as the two jars will not work properly unless their outer coatings are connected.

Question 16. Describe the Wimshurst machine.

Answer. Silvanus Thompson describes it as follows:

In this, the most widely used of influence machines, there are no fixed field-plates. In its simplest form it consists of (Fig. 23) two circular plates of varnished glass, which are geared to rotate in opposite directions. A number of sectors of metal foil are cemented to the front of the front plate and to the back of the back plate; these sectors serve both as carriers and as inductors. Across the front is fixed an uninsulated diagonal conductor, carrying at its ends neutralizing brushes, which

touch the front sectors as they pass. Across the back, but sloping the other way, is a second diagonal conductor, with brushes that touch the sec-

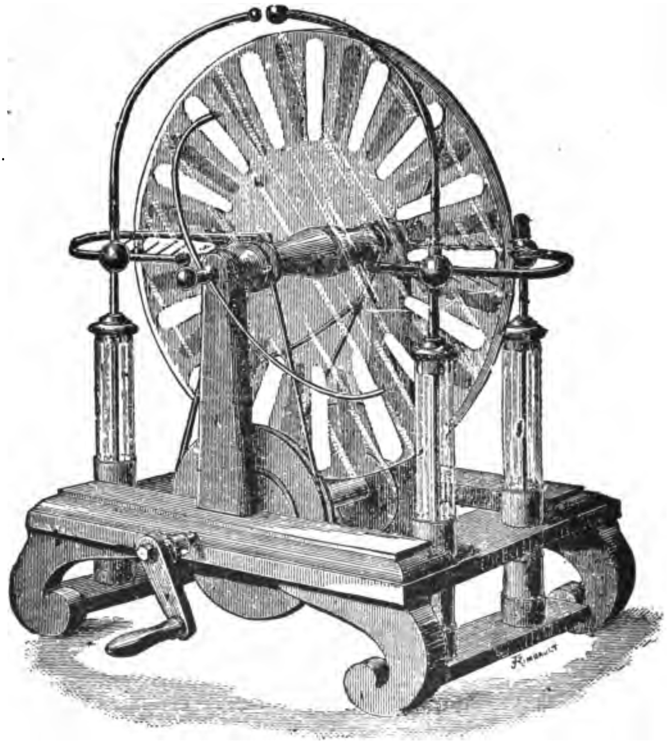

Fig. 23. A Wimshurst Electrical Machine.

tors on the hinder plate. Nothing more than this is needed for the machine to excite itself when set in rotation; but for convenience there is added a collecting and discharging apparatus. This consists of two pairs of insulated combs, each pair having its spikes turned inwards

toward the revolving disks, but not touching them; one pair being on the right, the other on the left, mounted each on an insulating pillar of ebonite. These collectors are furnished with a pair of adjustable discharging knobs overhead; and sometimes a pair of Leyden jars is added, to prevent the sparks from passing until considerable quantities of charge have been collected.

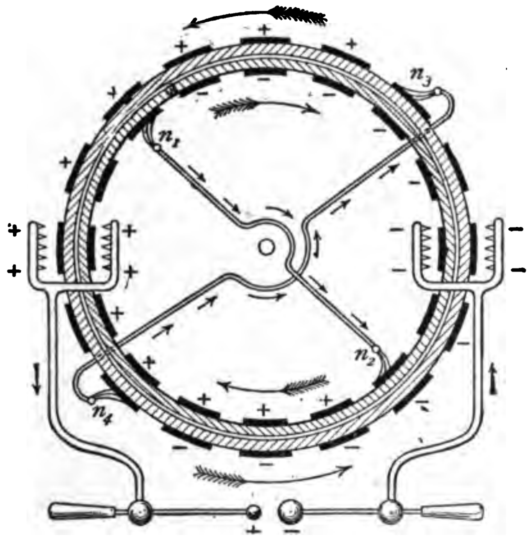

Fig. 24. The Wimshurst Machine laid out in diagrammatic way, to show principle of its operation.

The processes that occur in this machine are best explained by aid of a diagram (Fig. 24), in which, for greater clearness, the two rotating plates are represented as though they were two cylinders of glass, rotating opposite ways, one inside the other. The inner cylinder will

represent the front plate, the outer the back plate. In Figs. 23 and 24 the front plate rotates right-handedly, the back plate left-handedly. The neutralizing brushes n_1, n_2 touch the front sectors, while n_3, n_4, touch against the back sectors.

Now suppose any one of the back sectors represented near the top of the diagram to receive a slight positive charge. As it is moved onward toward the left it will come opposite the place where one of the front sectors is moving past the brush n_1. The result will be that the sector so touched while under influence by n_1 will acquire a slight negative charge, which it will carry onward toward the right. When this negatively-charged front sector arrives at a point opposite n_3 it acts inductively on the back sector which is being touched by n_3; hence this back sector will in turn acquire a positive charge, which it will carry over to the left. In this way all the sectors will become more and more highly charged, the front sectors carrying over negative charges from left to right, and the back sectors carrying over positive charges from right to left. At the lower half of the diagram a similar but inverse set of operations will be taking place. For when n_1 touches a front sector under the influence of a positive back sector, a repelled charge will travel along the diagonal conductor to n_2, helping to charge positively the sector which it touches. The front sectors, as they pass from right to left (in the lower half), will carry positive charges, while the back sectors, after touching n_4, will carry negative charges from left to right. The metal sectors then act both as carriers and as inductors. It is clear that there will be a continual carrying of positive charges toward the right, and of negative charges to the left. At these points, toward which the opposite kind

of charges travel, are placed the collecting combs communicating with the discharging knobs. The latter ought to be opened wide apart when starting the machine, and moved together after it has excited itself.

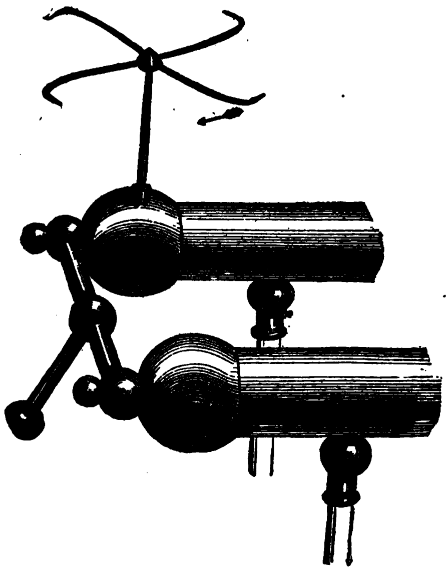

Fig. 25. Electrical Wheel.

In larger Wimshurst influence machines two, three, or more pairs of oppositely-rotating plates are mounted within a glass case to keep off the dust. If the neutralizing brushes make good metallic contact these machines are all self-exciting in all weathers. Machines with only six or eight sectors on each plate give longer sparks, but less frequently than those that have a greater number. Mr. Wimshurst has designed many influence machines, from small ones with disks 2 inches across up to that at South Kensington which has plates 7 feet in diameter.

Prior to Wimshurst's machine Holtz had constructed one with two oppositely-rotating glass disks; but they had no metal carriers upon them. It was not self-exciting.

Question 17. Give some experiments showing the action of electricity.

Answer. Example 1. If a pivot be erected on the knob of an electric machine and a small wheel with wire spokes bent as shown in Fig. 25 is balanced on the pivot, the electrical winds coming from the pointed ends will drive the wheel around.

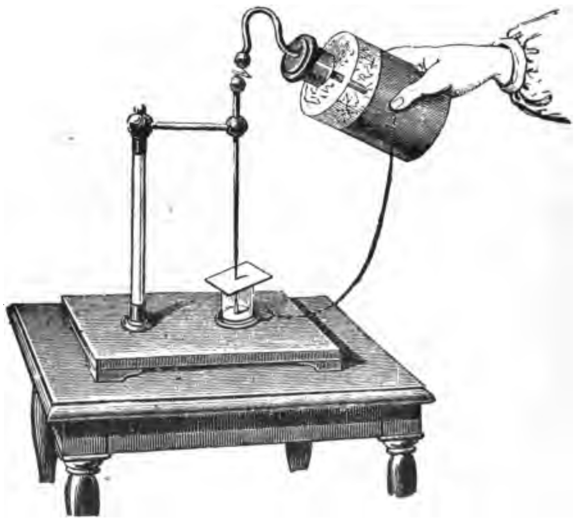

Fig. 26. Puncturing a Card with Spark from a Leyden Jar.

Example 2. A card may be punctured as shown in Fig. 26. There will be a burr on both sides of the hole in the card as if the material were pulled out from the card on both sides at the same time.

Example 3. A fine wire melted as shown in Fig. 27.

Example 4. When an electrical machine is actuated in the dark, accompanying the slight crackling which indicates leaking, at several points on the frame may be seen luminous appearances, called brushes; and if a conductor, a wire, or the hand, be presented toward the terminal of

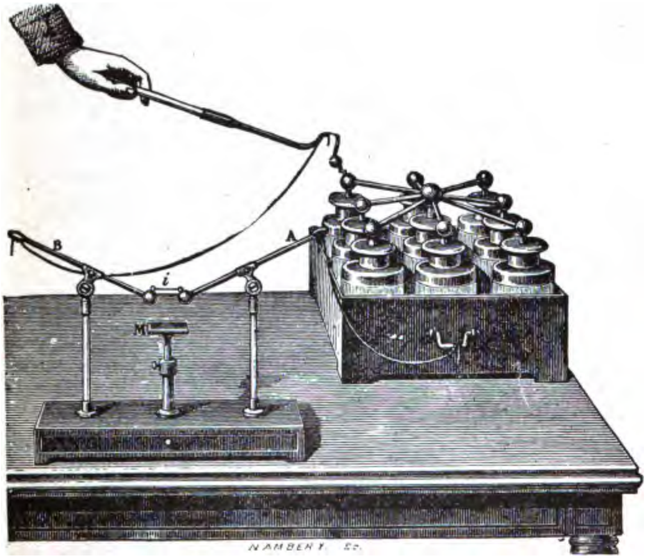

Fig. 27. Melting a Wire with a Battery of Leyden Jars.

the machine, just beyond the striking distance of a spark, one of these brushes will reach for the object so presented. The brush discharge consists of a short stalk, from which spreads a shape not unlike a palm leaf fan, consisting of rays which become thinner and lighter towards their outer extremity.

Example 5. If a doll's head having hair, be placed on the terminal of the machine, and the machine actuated, the hair will tend to straighten out in all directions, and will reach for the hand or other conductor presented. Discharging the machine by placing its terminals in contact, will restore the hair to its normal condition.

Example 6. A human leyden jar may be made by a person occupying a stool or chair, the legs of which are standing in dry India rubber overshoes, in tumblers, or in telegraph insulators. In this position the human leyden jar is capable of being charged, and of giving shocks to parties standing on the floor or ground. The hair of the human jar will stand on end if the charge is considerable, and be attracted by the approach of any conductor. The charge may be silently discharged through a fork or needle held in the hand.

Example 7. Attach a rod or heavy wire to the terminal of the machine, having the curved shape of a shower bath standard, and terminating in a metal band, the lower edge of which is fitted with points like an inverted crown. One sitting or standing beneath such an attachment will feel a very perceptible breeze.

Example 8. Approach the knob of a machine with a sharp needle held in the hand, and the discharge will be noiseless and not unpleasant. If in a darkened room, the discharge will be seen to resemble a blue flame.

Question 18. It is said that static electricity is only on the surface of charged bodies. Is this true?

Answer. Yes, as is shown by this experiment.

On the top of a rod of glass which is fastened to a sufficiently heavy base, a brass ring is fixed in a vertical position. To this ring, much like a minnow or landing or

butterfly net frame, is attached a fine linen bag, which runs down to a point—like an elongated cone. A silk thread extends from the apex or point of the cone, in each direction, so that the bag may be reversed at will by pulling on the one thread and loosing the other. Now, when this bag is charged a test shows electricity on the outside, and none on the inside of the net, in all cases. Reversing the bag reverses the surface electrified, no matter how often or how suddenly the change is made. See Fig. 28.

Fig. 28. Static Electricity always stays on Outside of Body.

Question 19. Is the charge spread evenly over the whole surface?

Answer. No. The density of electricity residing on the surface of a conductor sufficiently removed from bodies affecting it as to be uninfluenced by them, is materially dependent as to distribution, on the shape of the charged body. For instance, a perfect metallic sphere

shows the same electrical density over all portions of its surface, and while the charge of a metallic disc is hardly appreciable on the two surfaces, yet close to the edges it increases rapidly to the outer limit of the body. See Fig. 29.

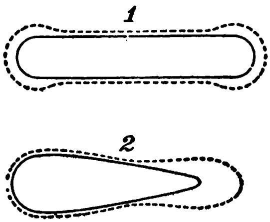

Fig. 29. Distribution of Electrical Charge over the surface of a body, showing influence of edges and points.

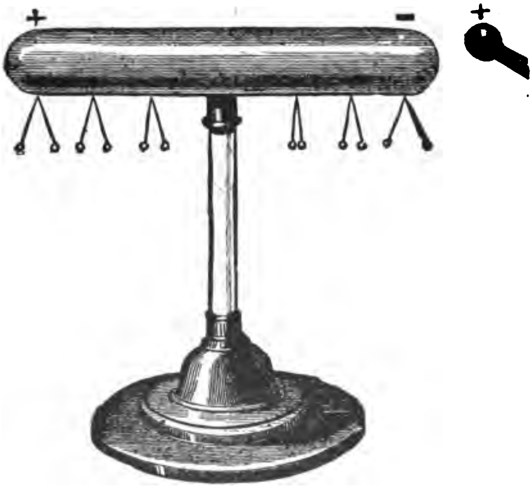

Fig. 30. Charge on a Conductor. Shows Density at Different Points.

This density increases at all pointed as well as rounded extremities. The density is greatest on the most pro-

jecting parts of the surface, or those which have the sharpest convexity, while hollows and indentations show little or no charge. In consequence of this strain, at a sharp projection on a charged conductor, or still more markedly, at a point, as in a sharpened wire, the condensation of such an amount of force within such small space produces a very rapid escape of electricity from such points. For this reason conductors which it is desired should retain their charge should have no edges or points, and must be very smooth. This is why the terminals of leyden jars and other similar apparatus are in the form of knobs and the combs of electrical machines are, like lightning rods, pointed, to facilitate silent, rapid leaking.

The density of the charge is also shown by the relative repulsion of the pith balls at different points on the surface, as in Fig. 30.

LESSON 6.

LIGHTNING.

ATMOSPHERIC ELECTRICITY.

The similarity in the effects of lightning and those of the electric spark enlisted the minds of the earliest physical investigators. Lightning ruptures and disintegrates substances opposing its passage, and where these are combustible, often ignites them. It is capable of producing all the effects of heat in melting metals, and volatilizing them, and leaves behind it, in many instances, the odor which we recognize as that pertaining to ozone. This odor is the same that is observed when an electrical machine has been working a few minutes. To Franklin is given the credit of thoroughly identifying the phenomena of proving experimentally with his historic kite, and the aid of leyden jars, that, excepting the factors of quantity and intensity, the two were one.

Franklin enumerated the following specific characteristics pertaining to, and tending to show that lightning and the spark were but different manifestations of static electricity: "Giving light; color of the light; crooked direction; swift motion; being conducted by metals; noise in exploding; conductivity in water and ice; rending imperfect conductors; destroying animals; melting metals; firing inflammable substances; sulphureous smell (ozone); and similarity of appearance between the brush discharge from the tips of masts and spars sometimes seen at sea,

called St. Elmo's fire by the sailors, and the slow escape from points on an electrical machine or a leyden jar."

The cause of electrical charges in the atmosphere is unknown, there are half a dozen explanations any one of which or all may be correct.

A Brush Discharge of Lightning.

It is generally agreed, however, that the cause of lightning is the condensation of water vapor in clouds.

Thunder Storms.—One of the most interesting manifestations of statical electricity is the thunder shower which is brought about in this way. Although bodies can-

not be charged throughout their substance, the electricity being always on the surface of the body; yet clouds seem to be electrified all the way through. This is because a collection of little particles of water, like a rain cloud, can have a charge on the surface of each particle.

As the particles of water fall by gravitation many touch and unite, so that the charges of say eight small drops are now in a drop weighing eight times as much, but which has only half the surface of the eight, hence the pressure is four times as large. This occurs in the following manner:

Since the surface of a sphere is equal to the product of the square of its diameter and the fraction twenty-two sevenths and the volume of a sphere is equal to one-sixth of the product of twenty-two sevenths and the cube of the diameter, we can calculate as follows:

Eight spherical rain drops each 1 mil* in diameter have a total surface of 25 sq. mils. They have a total volume

---

* NOTE.—A mil is the name given in machine shops and in all electrical work to one-thousandth of an inch.

The mathematical work of the above is here given in full.

Twenty-two sevenths is a convenient and quite accurate way of expressing the number 3.1416.

Total surface of eight spheres

$8 \times 3.1416 \times 1 \times 1 = 25$ sq. mils.

Total volume of eight spheres

$8 \times 0.166 \times 3.1416 \times 1 \times 1 \times 1 = 4.2$ cu. mils.

Volume of the large sphere $= 4.2$ cu. mils.

Diameter of large sphere is the cube root of

$4.2 \times 6 \div 3.1416 = 8$ mils.

Cube root of $8 = 2$ mils.

Surface of large sphere

$3.1416 \times 2 \times 2 = 12.5$ sq. mils.

$25 \div 12.5 = 2$. So large sphere has only half surface of eight small ones.

of 4.2 cu. mils. Now the sphere composed of the eight drops has the same volume i. e. 4.2 cu. mils and we can find its diameter from the rule: The diameter of a sphere is the cube root of the continued product of its volume, six, and seven twenty-seconds. Applying this we find the diameter to be 2 mils, hence its surface is 12.5 sq. mils. That is exactly one-half the surface of the eight separate drops.

Therefore the eight charges having been squeezed into the surface where only two were before, the pressure must be four times as great.

By the repeated union of these larger drops, the pressure becomes very high, and meanwhile the influence of the charged cloud is to accumulate a charge of the opposite name in the earth under the cloud. This in turn increases the pressure. When finally the pressure gets high enough the air is punctured, and the spark jumps between earth and cloud. It literally punches a hole in the atmosphere and the inrush of air to fill the hole causes the loud sounding thunder.

There are two kinds of atmospheric electricity different enough to need different devices to guard against their effects. Some forms of lightning arresters combine both devices in the one piece of apparatus.

Lines are sometimes struck by lightning. This means that an accumulation of electricity suddenly makes connection with the line, discharging through it, its machinery and instruments.

A stroke discharges violently and cannot be discharged by degrees, for the line is not strained until the lightning strikes.

Lines are often affected by "static," which means that

electricity has accumulated on the line until its pressure is high enough to do damage when discharging along the line through machinery, etc.

Static changes can accumulate on long open air lines as well as on lead sheathed cables.

The cable insulator makes a dielectric and the lead cover and copper conductor the two plates of a condenser.

In the open air line the two wires of the circuit form the plates and the air between the dielectric. Also the two wires together and the earth form two plates with air as the dielectirc.

A transmission line 150 miles long may have a capacity of 3 mf, i. e. 1 mf per 50 miles.

Both these effects, static and strokes are summed up in the one word "lightning."

Static charges may be discharged little by little as they accumulate, so that when properly protected a line never has a static charge on it great enough to do any damage.

STATIC EFFECTS ON CIRCUITS.

On high voltage alternating current lines not only lightning makes trouble but accidental grounds, and switching operations some times cause "static effects."

This use of the word static is hardly a good one as these effects are all due to a wave of electricity flowing over the circuit. This wave is the flow of an electrostatic charge from one point of the circuit to another.

When a disturbance is created at any point of an electric circuit as the sudden opening of a field circuit, an arc jumping across the lines, the release of a large "bound" static charge, or the striking of lightning, etc., a set of

waves of electricity are started just as when a stone is thrown into a narrow stream of smooth water.

Our troubles are caused by "static" electricity, but are actually produced by the wave or surge following the disturbance.

The damage done by a surge depends on the condition of the circuit, whether dead,* live or loaded, the excellence of its arresters in design and state of repair.

We will make this distinction between lightning and other static troubles.

When we say *lightning* we mean an actual stroke and its effects at the point of striking.

When we say *surge* we mean any or all static electrical troubles on the lines at points where the lightning did not strike.

Lightning can do damage by striking and producing a surge at the same time.

A surge is electricity at very high pressure and very great frequency; the normal current on a line is of moderate pressure and low frequency.

The normal current is produced by the generators.

Surges may be produced by

1. Switching off live lines from a station.
2. Switching on dead transmission lines, branch lines, transformers, or underground cables to a station or to a live line.
3. Short circuits which are sudden.

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*A dead line is one not connected to any source of electricity. A live line is one connected to a generator in operation or another circuit and has pressure on it ready to deliver power. When lamps, motors, etc., are connected to a live line it carries the current to operate them and is called a loaded line.

4. Grounds or partial short circuits which occur suddenly.

5. Lightning stroke.

By high pressure we mean any pressure over 50% greater than the line voltage.

Frequency is best explained as follows:

If the feed wire of a city trolley line be cut and a pressure indicator inserted the pointer will stand rather steady at about 500 volts. This shows a steady current.

If, however a feed cable from one of the main power stations to a sub-station be cut and a pressure indicator inserted (called an oscilligraph), the instrument will show that the pressure is constantly and very rapidly changing from a high value to a low one, then reversing and going down to a high negative value and coming back to zero.

The pressure keeps rising and falling and alternating positive and negative.

It will make from 15 to 33 of these complete changes, called cycles, every second. The frequency with which these changes occur is called the frequency.

Frequency is then the number of cycles per second.

Take a transmission line delivering power at the distant end where the capacity is about 3 mf.

While this line is in operation supplying power, the current varies, according to the load. When all the motors it supplies are stopped and all the transformers at the other end are cut off there is no load but still about 50 amperes flow into the line.

This current is charging the line, that is, keeping up the voltage of the line; for the line is a condenser and takes current to charge it.

If a switch is opened when the line is loaded there would be an arc formed at the switch blades on account of the large current broken and the discharge of the line itself.

A Lightning Stroke.

If a switch is opened when the line is simply alive, that is, charged but not loaded, there is a slight arc at the switch due to the discharge of the line.

If the generators are stopped and the line is "dead" of course there is then no arc at the switch opening.

The arc formed by the opening of a loaded line allows

the line to discharge itself across the arc, but when the switch to a live line is opened quickly the small arc dies out, leaving the line lightly charged. The line will now discharge itself at the weakest point along its insulation unless provided with arresters to discharge it in a harmless manner.

The surge of the charge may raise the pressure on this cut out* line to double the pressure of the generators. A 22000 volt line may rise to 44000 volts when suddenly cut out.

When a single phase generator (See Lesson 28) is grounded at one terminal and a "live" branch line connected to its other terminal is cut at the switch-board the pressure caused by the surge may rise to four times the original pressure. So a 40000 volt line might have one of its branch lines rise to 120000 volts.

The two cables from a single phase generator to the switch board are called its terminals.

When a dead line is "cut in"* its capacity must be filled up and there is a sudden rush of current into it. This produces a surge along the line and when the line is short the pressure may rise to double the normal pressure. When the line is long it hardly ever rises to quite double pressure.

It is interesting to know that the first dead line switched on to the generators has the least rise in pressure, and the last switched on the greatest. So the line with the weakest insulation or poorest arresters may be switched on first.

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*To cut in a line is to connect it to the generator or to the main transmission line; to cut out is to disconnect it. A cut out line is one which has been disconnected.

When a "dead" transformer is connected to a live line there is a surge, and due to the choking effect of the coils in the transformer, this surge only penetrates a short distance. The turns of wire near the end of a transformer are insulated with extra thickness of material to protect them, and arresters should be placed near each transformer to rid the line of the surge.

PROTECTION FROM LIGHTNING.

Persons.

Question 1. What precautions should people take during lightning discharges?

Answer. Do not stand in the open doorway of a building or under a single tree in a field. Standing under a group of trees is not so bad. Do not stand near a wire fence.

Question 2. Won't steel articles attract lightning?

Answer. No, nothing attracts lightning, it merely goes by the shortest path whose resistance is fairly low.

Question 3. Is not staying in a locomotive dangerous, especially electric ones?

Answer. No, it is the safest place you can be, as the metal is all around and acts as a shield, carrying the discharge safely past the person.

Question 4. What is to be done to a person struck by lightning?

Answer. Treated like a person who has been suffocated, and artificial breathing begun at once, as follows:

Howard's method of producing artificial respiration has this advantage over other methods in that it can be successfully practiced by a single person, instead of two, and at the same time is equally efficacious.

"Place the subject on his back, head down and bent backward, arms folded under the head (under no conditions raise the head from the ground or floor). Place a hard roll of clothing beneath the body, with the shoulders declining slightly over it. Open the mouth, pull the tongue forward, and with a cloth wipe out saliva or mucus. Thoroughly loosen the clothing from the neck to the waist, but do not leave the subject's body exposed, for it is essential to keep the body warm; kneel astride the subject's hips, with your hands well opened upon his chest, thumbs pointing toward each other and resting cn the lower end of the breastbone; little fingers upon the margin of the ribs and the other fingers dipping into the spaces between the ribs. Place your elbows firmly against your hips, and using your knees as a pivot press upward and inward toward the heart and lungs, throwing your weight slowly forward for two or three seconds, until your face almost touches that of your patient, ending with a sharp push which helps to jerk back to your first position. At the same time relax the pressure of your hands so that the ribs, springing back to their original position, will cause the air to rush into the subject's lungs. Pause for two or three seconds, and then repeat these motions at the rate of about ten a minute, until your patient breathes naturally, or until satisfied that life is extinct. If there is no response to your efforts persistently and tirelessly maintained for a full hour, you may assume that life is gone.

"Hot flannels, water bottles, bricks, and warm clothing will aid in recovery. Warmth should be maintained, but nothing must prevent persistent effort as above described. Stimulants in small quantities may be administered after swallowing is possible, and sleep must be encouraged, as

one of the best recuperatives. Get a physician as early as possible.

The treatment of persons shocked by electric light or power currents is identical with that for lightning stroke.

Buildings.

Question 5. Are lightning rods of any use?

Answer. Yes, if properly installed they offer a great protection.

Question 6. What material is best for lightning rods?

Answer. Copper, as its conductivity is high, and so is much lighter, smaller and neater in appearance than an iron rod.

Question 7. What should they weigh?

Answer. A copper rod six ounces to the lineal foot and an iron rod two pounds per lineal foot.

Question 8. What kind of rod should be used?

Answer. We really do not mean a rod, the word being used in a general sense. The best form is a tape or flat thin bar.

Question 9. What kind of tips should be used?

Answer. They should be pointed.

Question 10. Why is this?

Answer. The points tend to discharge the electricity of the earth to the air and thus relieve the tension in the atmosphere.

Question 11. Where should the rods be placed?

Answer. Tips should be erected on all parts of building projecting above the roof, such as cupolas, chimneys, gables.

Question 12. What should be done to cornices, ornamental iron work, etc.?

Answer. They should all be connected by a soldered joint to a "rod."

Question 13. Should the rod be insulated from building?

Answer. No. It is certainly unnecessary from an electrical point of view and is troublesome and expensive.

Question 14. Can the "rod" be run inside the building?

Answer. Never. This would be very dangerous, as lightning if it jumped from rod would surely cause great damage.

Question 15. Must the "rods" be run straight?

Answer. It is better to run from each point on the roof as straight to the ground as possible, avoiding all sharp bends, as these give the lightning a chance to jump off.

Question 16. Does each point protect a certain area?

Answer. No. The amount of space protected by a point varies. A sudden rush or disruptive lightning discharge may strike a building very near a point. Hence the more points the greater safety.

Question 17. How are the lower ends of "rods" connected to earth?

Answer. By being well soldered to water pipes or to a plate of copper about 3x3 ft. buried in moist earth.

Question 18. If the rods pass near metal work gas pipes, etc., what should be done?

Answer. Connect them to the rod by wires whose joints are well soldered.

Question 19. Why should the joints be soldered?

Answer. Because the resistance of an old or badly made joint will sometimes cause the lightning to jump off the rod. Every joint in the rod and connections should be soldered.

Question 20. How should lightning be prevented from entering buildings by the line wires?

Answer. Use lightning arresters at the point where they enter the building.

Question 21. What is a lightning arrester?

Answer. It is a device designed to protect electrical apparatus from lightning or atmospheric electricity.

Question 22. Does it stop the lightning?

Answer. No, the name arresters is misleading. They do not stop the discharges, but turn them aside to a conductor which leads to the ground.

Question 23. What circuits need protection?

Answer. Any circuit which has a part running out doors, or any circuit connected to one running into the open air.

Question 24. What kinds of circuits need protection most?

Answer. Long lines, lines running over hills or mountains.

Question 25. Does the kind of power on the line affect the liability of lightning discharge?

Answer. No, any kind of line from telegraph to power transmission is equally liable to be struck.

Question 26. Do the station men sometimes disconnect the dynamos from the line to prevent the line being struck?

Answer. No, they do it when they mistrust the lightning arresters' ability to protect the dynamos. Cutting the dynamos off puts them in safety, but the line is not protected. A dead line is just as apt to be struck as a live one.

Question 27. Are some parts of the country troubled with lightning more than others?

Answer. Yes. In the Rocky Mountains lightning discharges are very numerous and severe.

Question 28. What trouble may result from lightning striking a line?

Answer (1) Burning of insulation on wires in instruments and machines.

(2) Puncturing insulation of machinery, like dynamos or transformers. Either of these destroys the insulating value of the material.

(3) Melting of wires or fusing together metal parts which are in contact.

(4) Dangerous injuries to persons.

(5) Fire caused by an arc jumping across inflammable material.

(6) The insulators are sometimes cracked or even splintered.

(7) Poles are splintered or sometimes shattered.

(8) A cable forming a part of the current is more likely to have its insulator punctured than any other part of the circuit. This is a very troublesome and costly thing to repair.

This applies to underground or underwater cables more than to those strung on poles.

Question 29. Does lightning follow the shortest path or the path of least resistance?

Answer. Unlike ordinary current electricity, lightning usually follows the straight, short path even if of enormous resistance.

Question 30. Does a break in the circuit stop lightning?

Answer. No, it will jump across and go on.

Question 31. Do coils have any effect on lightning?

Answer. Yes. Lightning cannot pass readily through a coil of wire. It will do so if this is the only path open to it, but if there is any other path not containing coils the lightning will usually take the path without coils. It sometimes jumps from turn to turn of a coil, thus getting past without going through.

Errata:—Illustration on page 102 should read Shunt Circuit in lower part instead of Short Circuit.

LESSON 7.

LIGHTNING ARRESTERS.

LOW VOLTAGE.

Question 1. What is the oldest form of arrester?

Answer. The saw tooth spark gap of the telegraph offices.

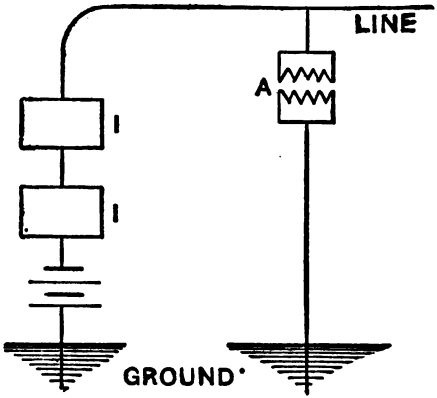

Fig. 31. The Saw-tooth Lightning Arrester as used on Telegraph Circuits. I and I are the Instruments and A the Arrester.

Question 2. Describe it.

Answer. Two brass plates with V-shaped points are set close to each other on an insulating base, one plate is connected to the line and the other to a ground plate buried in the earth. (See Fig. 31.)

Question 3. How does it operate?

Answer. The lightning being of an electrostatic na-

ture discharges from points readily, and being of an enormous pressure is able to jump the air gap between the points. The telegraph instruments contain electro magnets whose coils act as choke coils.

The lightning has the choice of the path through the instrument coils or across the air gap. It practically always takes the air gap and runs to the earth through the ground wire.

Question 4. What objection is there to this type of arrester when power circuits are to be protected?

Answer. The spark caused by the lightning in leaping across the air gap forms a conducting path between the plates.

The pressure on the line due to the generators sends the current across this path which forms an arc melting the edges of the plates.

This arc grows larger until it conducts enough current to "blow"* the fuses in the circuit, which interrupts the service.

The arcing of an arrester is always caused by the current of the line following the sparks due to lightning discharge.

Question 5. What is the easiest way of stopping the working current from following the lightning discharge?

Answer. Place small fuses (as in Fig. 32) in the ground wires of the arresters before they join to the common† ground wire. Then any working current following the lightning discharge will blow these fuses instantly,

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*Melt.

†A wire acting as a ground wire for several others is called a "common" ground wire.

leaving the main fuses unharmed. This will not interrupt the service.

Question 6. What is the objection to the arrangement?

Answer. Often the two fuses are blown, the arrester is useless and machinery left unprotected, there being no ground connection to conduct the discharge away.

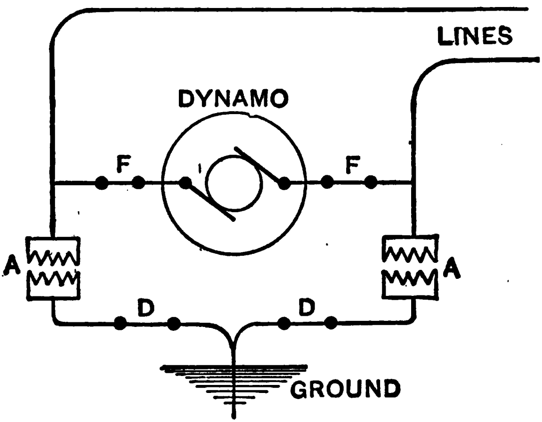

Fig. 32. The Saw-tooth arrester applied to a Dynamo. F, F are the regular fuses. D, D are the fuses for Arrester Circuit.

Question 7. But the fuses can be replaced?

Answer. Perhaps not before the next discharge has come. Moreover, a lightning arrester should allow the static charges which accumulate even in clear, dry weather to escape. These discharges sometimes snap across an arrester in the steady stream.

Question 8. What are some of the better ways of stopping the passage of the current after the discharge?

Answer. There are various ways, some methods put out the arc which is conducting the working current, and

some try to prevent an arc or at least make arc very small.

Question 9. How is the arc put out?

Answer. By air blast, electromagnetic action, mechanisms for lengthening the gap momentarily as the discharge passes, also use of non-arcing metals.

Question 10. How are arcs prevented?

Answer. Smothering the arc so that it doesn't form for lack of air; insertion of resistance into the discharge circuit which weakens the current following discharge so that it cannot hold an arc.

Question 11. What should be done if an arrester in a station holds its arc?

Answer. The arc should be beaten out with a cloth or broom, or it should be smothered with sand.

Dry powder fire extinguishers are very useful for this purpose, but water or liquid extinguishers should never be used.

Question 12. Where should arresters be placed?

Answer. At the point where lines enter or leave any building, and at intervals along the line.

Question 13. Why should they be placed along the line? Will not the protectors at the buildings protect the machinery?

Answer. It seems to be generally believed now that lightning runs along the lines in waves and that at one point it may be so weak that it will not jump to ground through a certain arrester but pass on, and the same charge a few miles further on, will either be discharged through an arrester there or if there is no arrester, do considerable damage.

Hence all the most exposed places on the line should certainly have arresters and a few strung along the line will not be wasted.

Question 14. What is the best arrester?

Answer. Each kind has its good points, some will not work on low pressures, others will not stand the severe test of Rocky Mountain use, but are reasonable in price and satisfactory in action in the more open and level parts of the country.

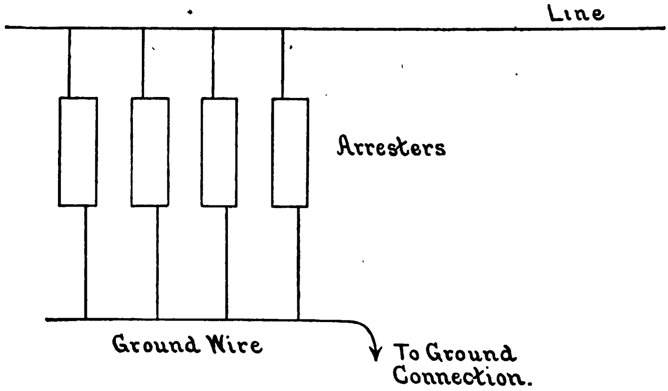

Fig. 33. Bank of Lightning Arresters.

Any arrester is hardly a complete protection unless combined with choke coils. (See Lesson 9.)

Question 15. Into what classes may arresters be divided as regards to the circuits and apparatus they protect?

Answer. (1) For use when currents are very small and voltages moderate as in telephone lines. The instruments are very delicate and need absolute protection.

(2) When currents are small and voltage moderate as in telegraph and signalling lines. Here the apparatus is heavier and less liable to damage.

(3) Power lines and lightning circuits where currents are heavy and voltage moderate, say up to 2500 volts.

(4) Power lines, transmission lines where the voltage is very high, say from 11000 up to 50000 or 60000 volts.

Question 16. Into what classes may arresters be divided as regards to the design of the arrester?

Answer. (1) Single gap arresters where one place is provided for the lightning to jump across.

Single gap arresters are often installed in banks in parallel* so that many places are provided at once.

The old saw tooth arrester is really a bank of single gaps.

(2) Multigap arresters, in which we have a number of single gaps in series.

These are sometimes simply a set of arresters in series. Each arrester being designed for say 2500 volts, using four in a series will protect a 10000 volt circuit.

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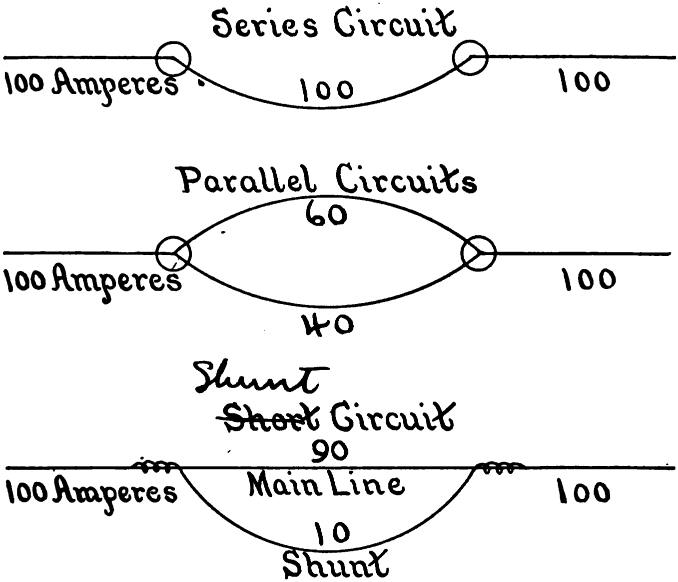
*The words series, parallel, and shunt will be more fully explained in Lesson 18, but it will be sufficient now to state that if a current goes through all of a number of instruments or resistances, they are in series. If the current splits and part goes through one set of instruments or resistances and the rest goes through another set then these two sets are in parallel.

Each set while in parallel with the other set may of course consist of several pieces of apparatus in series.

When a circuit is cut and a new piece of apparatus is inserted, this piece is in series with the other.

When a circuit has a new piece of apparatus attached by soldering on the wires without cutting the original circuit the new piece is a shunt circuit and the part of the old circuit is said to be shunted.

Usually they are so designed that a single arrester consists of a set of gaps in series. These arresters can be placed in series for high voltage.



The part of the main line which carries 90 amp. is shunted by the shunt which carries 10 amperes.

(3) Arresters with series resistances. The idea being that lightning will pass through the resistance without being obstructed much while the normal line pressure cannot send enough current through the resistance to hold an arc between the discharge points.

(4) Shunted resistances. In this type a resistance is put in parallel with the spark gaps. Experiment has shown that by proper design this is very effective in preventing an arc across the discharge points.

(5) Fixed gap length. In some arresters the gap length is fixed, and resistance (series or shunt), also, and the kind of metal used for the points, is used to suppress the arc.

(6) Lengthened gaps. The gap points are shaped like horns and the heat of the arc lengthens it by the uprush of hot air or the arc is forced up by magnetism.

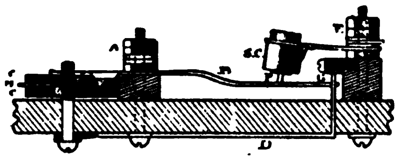


Fig. 34. Lightning Arrester and Stray Current Protector for Telephone, Bell and Signalling Circuits.

In other types the gap points are drawn apart by magnetism.

Question 17. What type of arrester is used for telephone circuits?

Answer. The protector is shown in Figs. 34 and 35. The line current enters at binding post A and passing along the spring B goes through the pin P through the wire of the coil SC on to post E, where the instrument wire is attached.

Each side of the apparatus is just alike, there being one piece for each line wire.

On the left of post A are two carbon blocks, C and C_1,

separated by a slip of mica M with a circular hole in it. The upper carbon block has a drop of fusible metal let into its lower face, but it is flush with the carbon.

The upper block is in contact with post A by a spring which holds it in position. The lower block rests on a metal plate, which is connected to the ground wire D.

When lightning or any pressure over 300 volts comes on the line it jumps across the air gap between the carbon blocks (whose length is equal to the thickness of the mica strip) and goes to ground. It at the same time melts the drop of metal, making a complete ground. The instruments are then absolutely short circuited and protected.

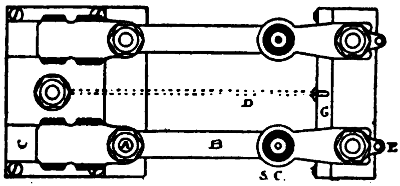


Fig. 35. Top view of Arrester shown in Fig. 34.

This means that there is a short and low resistance path for the current, which lightning will follow instead of going through the instruments.

Should there be a cross connection with other lines or a leak to the telephone line, the instruments could be damaged by the amount of current, while the pressure was far below 300 volts.

In this case the "sneak current," as it is called, goes from A along the german silver spring B, up through P and through the sneak coil SC.

The sneak coil is of very fine german silver wire, about 30 ohms resistance and in a few seconds this coil generates enough heat to melt a plug of fusible metal which holds the pin P in place.

The spring B then moves up and touches the ground strip G, thus grounding the line and protecting the instruments.

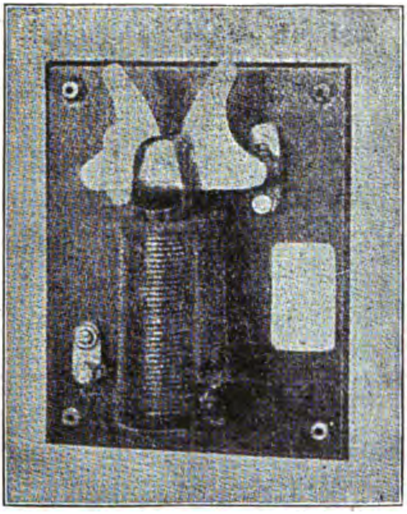


Fig. 36. Lightning Arrester with Magnetic Blow-out

Question 18. What type of arrester is used on moderate voltage lines?

Answer. One type is shown in Fig. 36. The air gap is between the curved plates. The magnet below is excited from the dynamo and the arc when formed is blown upwards until the space at the upper end of the curved plates is too long for the pressure to maintain the arc.

The instrument acts as if the arc were blown out by a puff of wind.

Another form of this arrester has two flat plates so surrounded by the magnetism that the blow out effect is stronger, and it is relied on, there being no horns to help. Both of these are used on direct current circuits.

Question 19. Describe an arrester for alternating currents at moderate voltage.

Answer. There is a non-arcing arrester for A. C.* work. It consists of seven cylinders, each one inch in diameter and three inches high. They are made of white

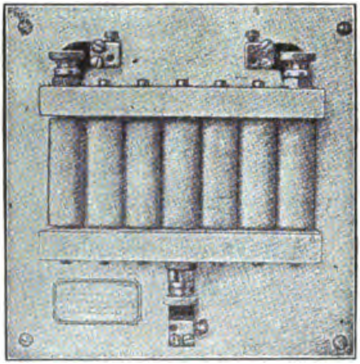


Fig. 37. Wurtz Non-arcing Lightning Arrester. Used with Alternating Current.

brass with a large percentage of zinc, and very little copper, in it. They are knurled or checkered so that the surface is covered with little points.

These cylinders are held in insulating strips so as to be about 1-64 of an inch apart. For low voltages the center

*Abbreviation for alternating current.

cylinder is grounded and the end ones connected to the lines.

When used on A C circuits the discharges which spark across do not cause arcs.

The probable reason is that the cylinders being close together, the spark makes a little explosion which blows

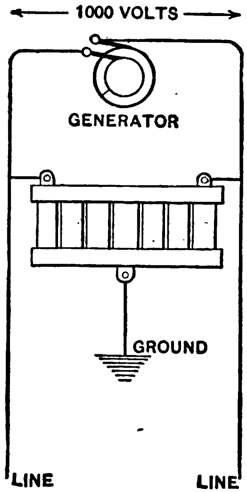


Fig. 38. Wiring diagram for 1000 volt circuits. One Arrester used.

the arc out, and the boiling of the metal where the spark jumps carries the heat away in the vapor and the spot is too cool to hold an arc.

The cylinders must be turned after each storm to present fresh surfaces for the next discharge.

A single arrester is shown in Figs. 37 and 38. Figs. 39 and 40 show the arrangements for higher voltages.

It will be noticed that this is of the multigap type.

[In Fig. 40 is shown the beginning of the "new idea" in lightning arresters which will be discussed at length further on.]

Question 20. How does the non-arcing arrester in Fig. 40 operate?

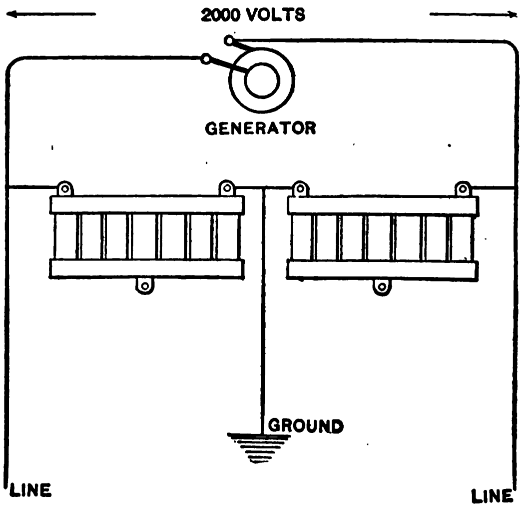


Fig. 39. Wiring diagram for 2000 volt circuits. Two Arresters used.

Answer. The operation of this arrester is as follows: The number of series gaps is adjusted to the voltage at which the arrester is desired to discharge. This is the real lightning discharger. The series resistance is small and so wound that it is as little like a coil in its choking action as possible. Its presence will prevent a large current flowing through the arrester while it is discharging.

If only as few series gaps as are shown were there, with a small series resistance, the dynamo current which fol-

lows the lightning discharge will cause an arc and burn the cylinders.

When shunted gaps are used the result is:

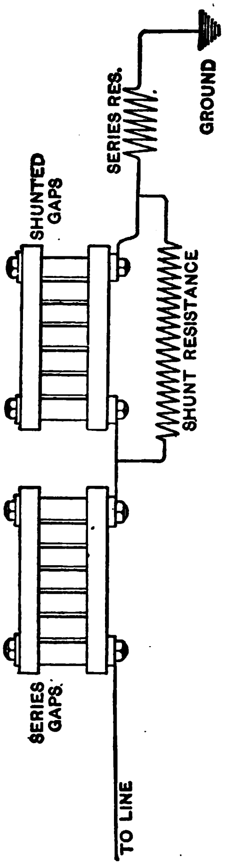


Fig. 40. Arrangement of Arresters and Resistances for High Voltages. This forms a Multigap Arrester.

The lightning followed by the line current passes through the series gaps. Then the lightning due to the choking action of the shunt resistance, sparks through the

shunted gaps, while the line current on account of the high resistance of the shunted gaps, passes through the shunt resistance.

There is then no line current in the shunted gaps to hold an arc. The lightning having now discharged the line current finds a series circuit, composed of the series gaps, the shunt resistance and the series resistance.

The shunt resistance being large, the total resistance of the arrester is large enough to shut off the line current entirely.

Had such a large resistance been in series with the series gaps at first the arrester would not have started to discharge and of course afforded no protection.

Question 21. Is there a non-arcing direct current arrester?

Answer. Yes, the non arcing direct current arrester is based on these facts.

(1) Lightning will pass over a non-conducting surface more readily than across an equal air gap.

(2) It will pass even more readily if the surface is covered with carbon.

(3) An arc cannot form where there is no air to help the material burn.

A lignum-vitæ block is charred in its center for about half an inch in width. Two metal plates are set flush in the block on each side of the charred strip.

A second block is screwed tightly over the first to keep out the air.

This arrester works on direct current up to 700 volts. The lightning passes easily from plate to plate; while the charred strip of about 50000 ohms resistance prevents the passage of current from the line.

The lightning cannot start an arc in this small space.

One plate is connected to a line wire and the other to the ground. Two should be used, one on positive wire and the other on the negative.

These arresters have been used with "smooth cored" alternating current generators furnishing 1000 volts pressure.

Question 22. Is there a small, cheap arrester for single instruments and small buildings, as switch men's cabins, tool houses, etc., and for use on electric light circuits?

Answer. Yes. A lightning arrester designed for alternating current (abbreviated A. C.) up to 350 volts pressure is shown in Fig. 41.

Where long secondaries are run from transformers, a necessity has been found for the use of lightning arresters. The demand for a low priced but effective and reliable arrester for this service has resulted in the arrester shown.

This device is for use on any A. C. circuit of 350 volts or less, and is suitable for protection of individual series A. C. arc lamps, as well as on incandescent lighting circuits. Its effectiveness when placed on wires at the entrance to buildings, store-houses, signal towers, etc., recommends its general adoption.

A detailed description of construction is given later. The general plan is shown in Fig. 41, where will be seen the two large circular discharge plates separated by an air-space of 1/50 (.020) inch at their beaded edges. Over this air-gap a heavy discharge may pass, while light discharges and static surges will pass to earth, more slowly, through the high resistance disc that separates the larger metallic discs. This disc is of permanent resistance and allows the passage of but an infinitesimal normal current, while permitting the escape of the high voltage static dis-

charges. In the event of the discharge being heavy, it will jump the spark gap, but the low voltage of the normal current will not maintain an arc, owing to the cooling effect of the heavily beaded disc.

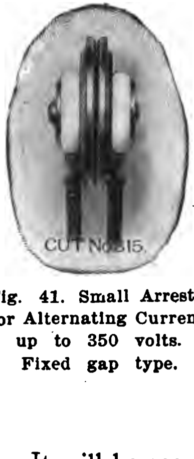


Fig. 41. Small Arrester for Alternating Current up to 350 volts. Fixed gap type.

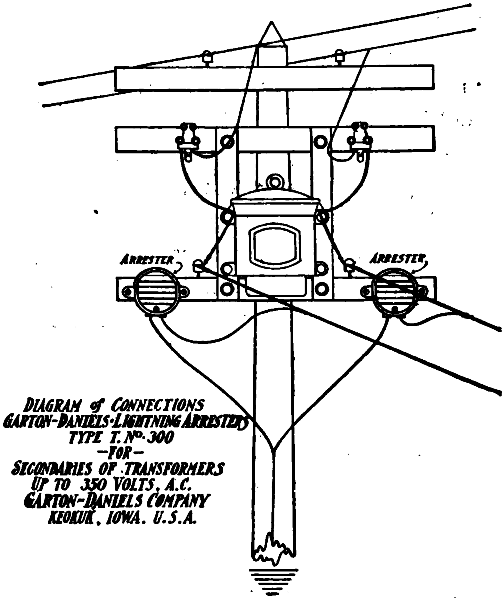


Fig. 42.

It will be seen that this device offers a choice of either of two paths, one highly efficient as an outlet for static surges, and the other (the spark-gap of 1/50 inch) a highly efficient path for lightning discharges.

When used on the secondaries of transformers, one arrester is necessary on each leg of the circuit. Same should be connected in a shunt path to earth as shown in Fig. 42.

As an arc lamp protector it is connected directly across

the terminals of the lamp as shown in Fig. 43, thus offering a path around the lamp, to the standard pole arresters, which should be distributed along the line at intervals. These standard pole arresters are, of course, connected between line and ground, and thus offer an easy escape for the discharges.

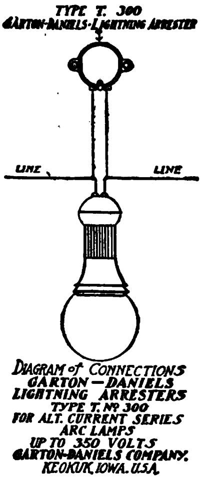


Fig. 43.

It has been customary in many cases to use standard forms of arresters in the same service for which this device is designed. These standard forms have the objection of higher cost, larger size, and, as all employ a much greater spark-gap distance, are not nearly so efficient as this Type T. arrester. Furthermore, the auxiliary path through the high resistance disc increases the efficiency of this arrester many times.

The device consists of the parts illustrated in Fig. 44 assembled as shown in side view Fig. 41. Parts Nos. 309 are two metallic discs, formed with a heavy bead around the circumference, the center being flat to make contact with the high resistance disc, No. 311. These parts are

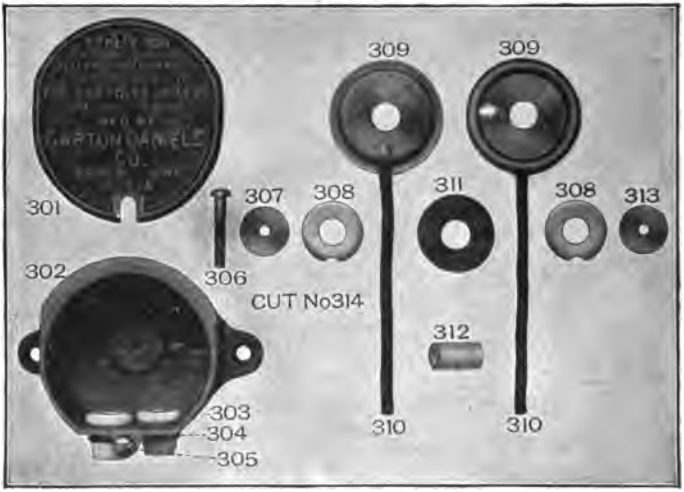


Fig. 44a. Parts of Arrester shown in Fig 41.

assembled on the insulating tube, 312. The high resistance disc separates the metallic discs so that the heavy beaded circles are separated by 1/50 (.020) inch. Parts Nos. 308 are insulating discs, also mounted on 312. The screw, No. 306, passes through steel washer, 307, tube, 312, and asbestos disc, 313, so as to clamp them together when screwed into weather-proof box, 302. The flexible leads, No. 310, pass through porcelain insulator, No.

303. The cover, 301, hooks over the top of box, 302, and is fastened in place by but one screw, 305. This cover is perfectly weather-proof. Complete, the arrester measures 3½ inches from center to center of supporting holes.

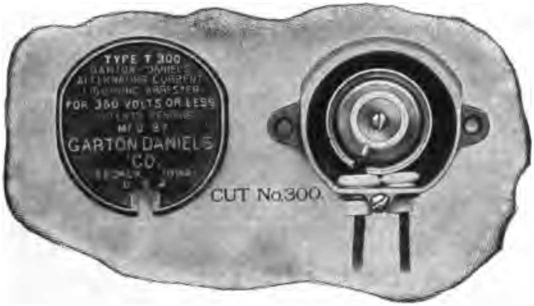


Fig. 44b. Arrester parts as shown in 44a assembled ready to screw cover on.

Protection of Lines.

Question 23. How should signal lines be protected?

Answer. When on pole lines an arrester should be placed on pole about every half mile; when run in conduits or tunnels one should be placed at each end of conduit or tunnel.

Question 24. How should telegraph lines be protected?

Answer. As the instruments are only placed in stations, an arrester at point where wires enter station is sufficient.

Question 25. How should telephone lines be protected?

Answer. A protector which contains a "sneak current" device should be placed in every line where it enters a building.

Question 26. How should feeders to trolley wire or third rail be protected?

Answer. Such lines are usually fairly short and not much exposed to lightning being carried on low poles. The arrester on the feeder at the station and one where the feeder connects to trolley or third rail should give ample protection.

Question 27. How should trolley wires or third rails be protected?

Answer. The arresters at the ends of the feeders ought to be sufficient for the trolley wire also.

If there are very few feeders it would be well to see that there is an arrester every half or three quarters of a mile. One to the mile will do, as trolley construction is very strong and not liable to damage.

The third rail lies along the ground and is seldom struck. If it were the mechanical strength of the rail itself and its insulators would protect them, although the lightning did side flash to the ground.

Question 28. What protection should motor cars or locomotives have?

Answer. There should be an arrester in the main circuits which furnish the power, and an arrester in the control circuits which control the motors. These two arresters should be of different styles. That for power circuits should discharge at 1,000 volts and that in the control circuits at 250 volts.

Question 29. What protection should be given to a trolley car?

Answer. An arrester should be placed on roof or under hood of such a capacity that there can be no chance of its failing to operate.

LESSON 8.

Lightning Arresters.

HIGH VOLTAGE.

An arrester of the two gap type with a magnetically lengthened gap to break arc is shown in Fig. 45, and its construction in Fig. 46. It is made for alternating or direct current work.

In order to increase the surface distance, so as to prevent breakdown between current carrying parts of considerable difference of potential, one of the discharge points is mounted on the end of the resistance rod B. This rod is held in position by the clamps at C and D. The distance from clamp C to upper discharge point A is 2¾ inches. The solenoid cut-out coil H is supported by brackets I and K, bracket K being so designed that it gives a surface distance on the porcelain base of 2¼ inches between K and lower discharge point bracket L. This is a total of 5 inches, which is a liberally safe surface distance on porcelain for 2500 volts.

To still further reduce the possibility of current jumping between parts, the line connection is at the top of the Arrester, from which the discharge passes downward in a practically straight path to ground connection. This path is indicated by the round dots in Fig. 46, the dashes showing the path of the normal current. It will be noted that the discharge goes through the section of the resistance rod C-D, the normal current being shunted through the

solenoid coil H. This energizes the iron armature J, which raises upward in the coil, opening the circuit between the discharge point M and lower end of armature. The discharge point M is stationary, so that the air-gap

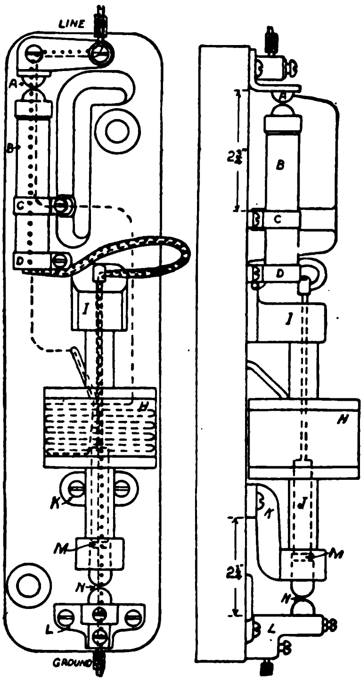


Fig. 45. 2500 volt Alternating Current Arrester. Mechanically lengthened gap type.

Fig. 46. Diagram of Arrester shown in Fig. 45.

at N is not changed by the operation of the Arrester. The arc is thus drawn out until broken inside the tube, which is practically air tight and prevents flying sparks or serious arcing. The upper end of discharge point M is car-

bon, so the arc is drawn out between the same and the iron armature. This combination prevents sticking or welding together.

3500 volt arresters are designed along the same lines as the 2500 type. They differ in width and length of base to accommodate the higher voltage rating per arrester unit. In the 3500 volt arresters is provided an additional air-gap near the line binding-post. This construction has proven in extended service to be perfectly safe, and satisfactory for the higher voltage rating of 3500 volts.

As the circuit is opened inside the tube and the air-gap adjustment is always the same, it is possible to use the small air-gap space. In this 2500 volt arrester, the air-gap distance is 3-32 inch, which is as small as can be used safely.

The cut-out is entirely automatic, restores itself by gravity, is instantaneous in operation, and prevents grounding the line, whether the discharge points are dirty from repeated operation or not. If the normal current follows the lightning over the air-gaps, it is shunted through the coil. The coil immediately cuts it off and the normal dielectric of the air-gap is restored.

To limit the flow of normal current that can follow the discharge to ground, the upper section of the resistance rod B is employed, there being approximately 250 ohms between discharge point A and clamp C in the 2500 volt arrester. This keeps the current down to a value that is broken readily by the cut-out, and is not enough resistance to impede the passage of the discharge.

This feature is particularly effective where a part of the circuit is grounded, or where the circuit is temporarily or accidentally grounded. This series resistance prevents a heavy short-circuit through the arrester. The cut-out

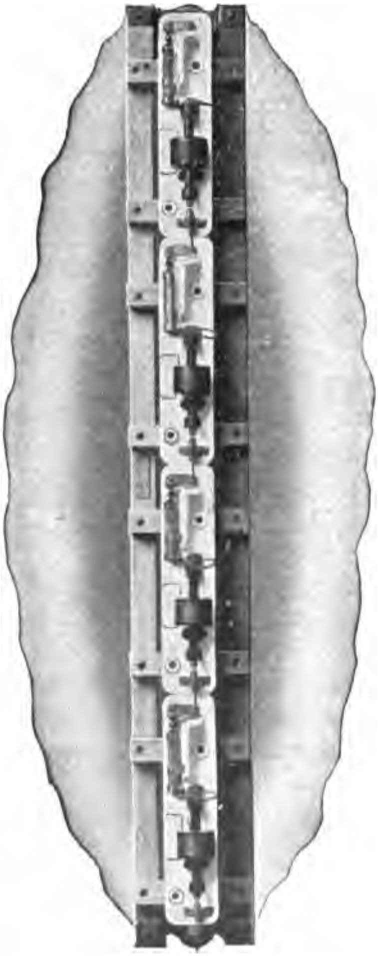


Fig. 47. 10000 volt Arrangement of Four 3000 volt Arresters.

readily interrupts the flow of normal current, and the arrester is again ready for another discharge.

The positive action of the cut-out renders the arrester independent of the condition of the discharge points, and they require no more than an occasional inspection.

When protection for higher pressures is desired a number of these arresters are often mounted in series as shown in Fig. 47.

The multigap arrester with graded shunt resistance for alternating current.

If a series of knurled cylinders of zinc alloy about 1/64 of an inch apart has the first one connected to a line and the last one grounded, there will be an electric strain all along the series due to the tendency of the pressure on the line to force electricity through the series to the earth.

Suppose a single gap between two cylinders will always prevent 400 to 600 volts from jumping across, but that 800 volts will be sure to jump.

Suppose you have a 22000 volt line and place 56 cylinders in line making 55 gaps, each gap will stand 400 so the 22000 volts will never spark across.

Suppose a lightning discharge increases the pressure on the line to 33000 volts, which makes 600 volts per gap. One would think that the gap will not be jumped, and that the insulation of the machines, etc., will be strained. The frequent occurrence of this will finally break down the insulation and a burnt out generator be the result.

However, an arrester of a large number of gaps works in a peculiar manner.

When the normal 22000 volts is on the arrester the

first gap has a pressure on it of 600 to 700 volts and each successive gap less and less on to the end.

The pressure does not distribute itself evenly over all the gap but piles up on the first few.

It is clear then that when the abnormal 33000 comes on the line that the first few gaps of the arrester have a pressure of 900 to 1000 on them, and the spark jumps across.

The state of affairs is now as if 52 gaps were placed as an arrester on a 31500 voltage. The first few gaps getting the highest pressure are sparked across.

This action takes place all along the 55 gaps, each gap nearest the line being sparked across by the concentration of pressure upon it, until all the 55 gaps are sparking. The discharge passes to the earth and the line is relieved.

Another peculiar thing now happens. When all the gaps are sparking the voltage distributes itself evenly over the arrester; so that now only 600 volts are across each gap and the sparks go out before any of the current of the line can flow through and cause arcs.

If line current should follow the lightning discharge this current by its action brings the arrester more quickly to the even distribution state, and the arcs go out.

If the discharge did not completely relieve the line a second one would immediately occur, or a succession of them until the pressure was down to 22000. At that pressure there would be 600 to 700 volts on the first gap and very little on the last.

It is evident that in designing a multigap arrester you cannot divide the line voltage by 400 and put in that many gaps in series and be positive that 22000 volts won't discharge through it under all conditions of regular use.

You must remember that extra gaps are needed as you increase the number in the arrester. Three gaps will hold 1200 volts while 120000 volts will go right through 300 gaps. Ten times as many gaps will not hold back ten times the pressure.

This arrangement of a large number of gaps called the multigap arrester has three excellent features.

(1) It will discharge at a very slight increase of pressure above the normal.

(2) It automatically stops discharging when pressure on line falls to nearly the normal pressure.

(3) Line current going through the arrester carries its own cure.

This condition of high pressure existing at the end of a series of gaps may be illustrated by connecting ten incandescent lamps (110 volt type) suddenly to a 1000 volt circuit. There will then be a surge which will generally burn out a lamp or two at each end of the series. Those lamps at the center of series will never be damaged.

Remember this is not a proof of the high pressure at the first gaps because the lamps are broken by a surge, but it does prove that pressures can pile up at a point in a circuit far above normal, and makes one willing to believe that the gaps might do a similar thing.

The objection to the multigap arrester is as peculiar as its action.

A static discharge is of low frequency and a lightning stroke discharge of high frequency.

A high frequency pressure causes a greater pressure on the first gap than a low frequency pressure.

Hence, an arrester discharges at a lower pressure for lightning-stroke, than for static accumulations,

If then enough cylinders are used so that the regular voltage on line won't break* down the gaps, there will be often static accumulations of higher voltages than is safe for line but of such low frequency that enough pressure will not be exerted on the first gap to start the arrester into action.

It is the multigap arrester with graded shunt resistances that solves this problem.

Low frequency pressures can only break down a few gaps as compared with a high frequency pressure of same voltage.

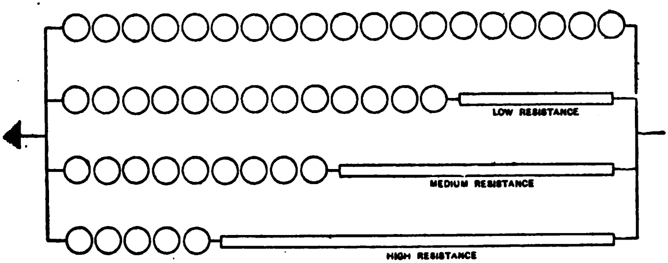


Fig. 48. Diagram of a Multigap Arrester in Imperfect Form.

Suppose as in Fig. 48 there are arranged between line and ground four circuits, one of 18 gaps, another of 12 gaps and a low resistance, a third of 8 gaps and a medium resistance, while the last has 4 gaps and a high resistance.

It will be seen that the opposition offered by any of the four circuits to 6600 volts will be perfect and no line current will pass through the arrester.

A lightning stroke of high frequency will pass through

*The words "break down" used with lightning arresters do not mean any damage to apparatus but merely refer to the discharge.

the 18 gaps quite easily. Surges will perhaps be unable to pass the 18 gaps, the frequency being too low, but will find their way through one of the other circuits. Static accumulations being of very low frequency will pass through the 4 gaps and high resistance while they could not get through any of the other three. Remember that any of these must be above the normal pressure to discharge. In fact, unless they were above normal voltage we would not care about them.

The objection to this arrangement of gaps and resistances is that a static charge of very high pressure and very low frequency might occur.

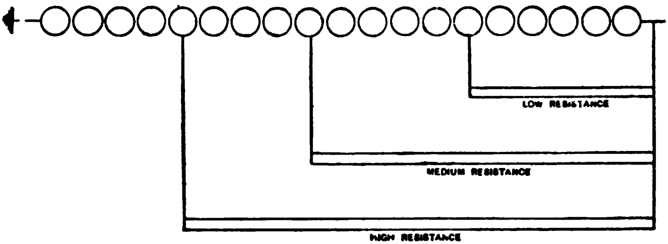


Fig. 49. Perfected Form of Multigap Arrester with Graded Shunt Resistances.

This could only break down the 4 gap high resistance leg* of the arrester on account of low frequency. It would discharge so slowly through the high resistance that the line would not be freed from the high pressure quickly enough to prevent damage.

The arrangement of gaps and resistances actually used is shown in Fig. 49. The multigaps are put in series and the three resistances are put in as shunts.

*Parts of circuits which have the same starting and ending points are often called legs.

This removes the objection just mentioned and incidentally uses far less cylinders in an arrester.

The action is just the same, each frequency selecting its own path. In addition to this each time the arrester acts no matter what the frequency, the whole line of gaps from end to end breaks down and relieves the line quickly.

In fact, with this arrangement we might say that the resistances are merely a device to enable a low frequency to break down more gaps than it usually can.

This action takes place as follows: When a low frequency discharge passes through the high resistance and sparks across the last 4 gaps; at the same time, part of it passes through the medium resistance, and as the last 4 gaps are sparking it is able to break through the 4 in front of it to them. This action occurs all the way up the arrester.

The action can also be explained in this way: The low frequency pressure passes through the three resistances and exerts its pressure at different points along the gaps. At only one place does it find few enough gaps between itself and the ground. This place is the last 4 gaps. It breaks these down and begins to discharge to earth. But now at the end of the medium resistance connection it finds only 4 unbroken gaps, and is able to break them down and it does so.

In this way the whole arrester breaks down in sections, even for low frequency discharges.

In Fig. 50 is shown a 2300 volt arrester with two resistances and in Fig. 51 is shown a set of cylinders mounted on slate base. These sets of cylinders are used in building up the 6600 volt up to 60000 volt arresters.

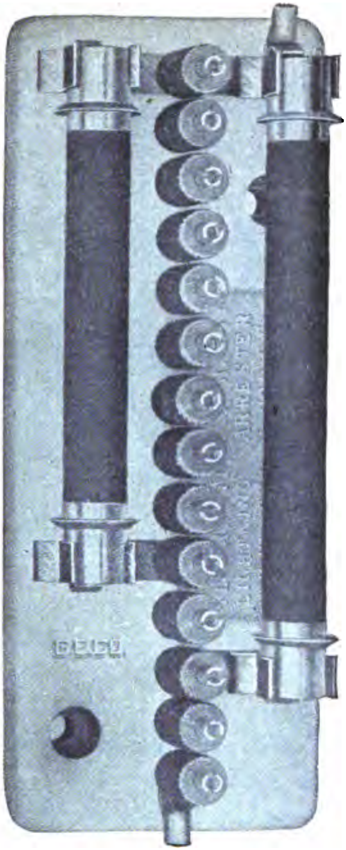


Fig. 50. A 2300 volt Multigap Shunt Resistance Arrester for Alternating Current.

With these high voltages a long spark gap shunted by a fuse is placed in series with the arrester. Then on a heavy short circuit the fuse blows and puts the spark gap in series with the arrester.

This prevents the destruction of the arrester and does not put it completely out of action. The fuse should be replaced as soon as possible. Frequent inspections should be made to see that cylinders are clean and the fuse in working order.

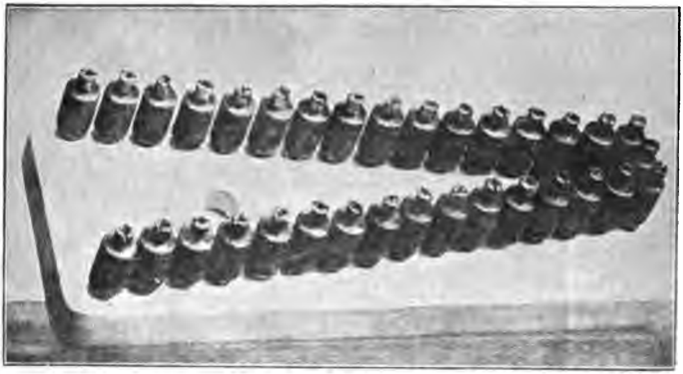


Fig. 51. Set of Cylinders on Slate Base. These are used as units to make up complete arresters.

PROTECTION OF LINES.

Transmission Lines.

Question 1. What is one of the simplest methods of protecting an overhead line?

Answer. Using a ground wire.

Question 2. What is a ground wire?

Answer. It is one or more wires strung parallel to the line and grounded at every pole. One is about as good as more and very much cheaper.

Question 3. In what position are they placed?

Answer. When there are two line wires one ground wire should be run on the top of thé pole, or two ground wires run; one at each end of the cross arm or another cross arm below the main arm.

When there are three line wires, one ground wire should run on top of pole or in the center of the triangle formed by the line wires, or three ground wires should be installed, one on top of the pole and one at each end of a cross arm under the main cross arm.

Question 4. Why are they run on glass insulators?

Answer. They must be tied to something and a cheap glass insulator is less expensive than some special device which is not an insulator. The fact that the glass is an insulator is not harmful, because a ground connection is made by a wire at every pole.

Question 5. Are the ground wires copper?

Answer. They are usually galvanized iron about No. 4 size but a stranded 3/8 "cable" is better.

Question 6. Is the iron wire as good as copper for a ground wire?

Answer. Yes, for electrostatic charges the size of the wire is of far greater importance than the material.

Question 7. Barbed wire is generally used, is it not?

Answer. Formerly it was, but engineers are now believing that the plain wire is as good, and being cheaper and much easier to handle is much more used than the barbed.

Question 8. What was the reason for originally using barbed wire?

Answer. It was thought that the barbs acted as discharge points to let the free charges escape quickly into the air.

Question 9. Do they not act that way?

Answer. They probably would if the free charge was not neutralized by the earth connection so quickly.

A plain grounded wire well connected to earth is sufficient protection.

Barbed wire is not as strong as a plain wire of equal weight per foot.

Question 10. Why are not ground wires always put above the line wire?

Answer. They used to be put above, because engineers thought the ground wire was a protection from a direct lightning stroke.

We now think that they are not much use in that case, so do not always put them above so as to have them struck first.

We often put them below believing that, in the way that they protect, they can do so as well from there as from above.

Furthermore, being below should they break they cannot cause short circuits by falling on the line wires.

A single ground wire is often put on the top of the pole for convenience, but a single ground wire with three line wires is sometimes put in the center so as to be equally distant from all three.

Question 11. How does a ground wire protect the line?

Answer. It seems to be a fact that lines are not often struck by lightning, but that thunder or electrical storms affect the lines by static charges very frequently.

This is done as follows: A cloud heavily charged with say positive electricity blows up over the line. There will be induced in the line a bound negative charge and

a free positive charge. This free charge will have a tendency to go to the earth. It may do so by leakage over and through the insulators of the line if the approach of the cloud is slow enough to allow it to do so, if not it jumps through the insulator puncturing it, or it may side flash over the insulators from wire to cross arm.

If a ground wire is present a bound negative and a free positive charge is induced in it.

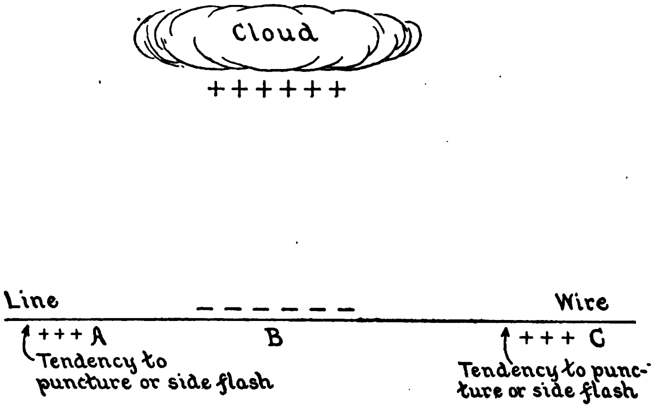


Fig. 52. Electrostatic Charges on a Line under a Thunder Cloud Without a Ground Wire.

This bound negative charge prevents as great an electrical separation on the line as the cloud alone would make and so the line does not become so highly charged. This is shown in Figs. 52 and 53.

In Fig. 52 suppose the cloud to cause an electrical separation in the line as shown. There will be a tendency to puncture or side flash at points A and C.

Now suppose the charge on the cloud to be neutralized by a lightning flash from cloud to earth. If it does not

strike the line at B and neutralize the negative charge there, it will leave this charge free and there will be a tendency to puncture or side flash at B. After this the charge at A and B will spread over the line with a surge.

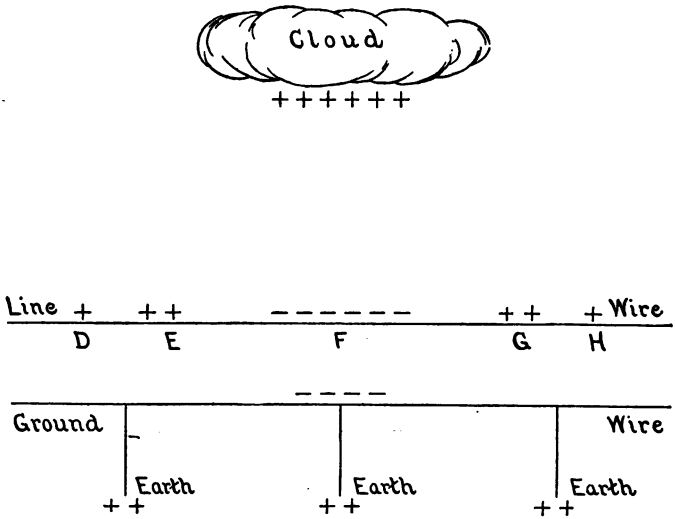


Fig. 53. Electrostatic Charges on a Line having a Ground Wire.

When the ground wire is there as in Fig. 53 the cloud induces a negative charge on the ground wire which is smaller than that on the line. It is smaller because the capacity of the ground wire is less than that of the line wires. It would be far too expensive to make the ground wire capacity nearly equal to the line itself.

The free positive charge on the ground wire goes to earth and the bound negative charge acts inductively on the free positive charge of the line. This causes the dis-

tribution of charge to be as is shown and the tendency to have static troubles at E and G is less than it would be without the ground wire.

Suppose now the cloud is discharged. The charge at F on line will not act as violently as that at B did, because the repelling effect of the negative charge on the ground line at F tends to spread out the negative charge on the line at F. Thus the tendency to static discharge at F is less than if ground wire were not there.

Question 12. What are the objections to a ground wire?

Answer. It is expensive to install. It is only a partial protection and other devices must be used with it.

Question 13. What is its chief value?

Answer. It prevents the splitting of the poles, and damaging of insulators.

Question 14. Does it protect the station?

Answer. No, it is a line protection.

Question 15. What other simple protectors are there?

Answer. The horn arrester is an extremely simple device.

Question 16. What is a horn arrester.

Answer. A horn arrester is as shown in Fig. 54. A single spark gap whose length is regulated by the pressure it is designed to withstand (say 6¼ inches for 90000 volts) has a wide spreading pair of horns attached, the ends being perhaps twelve feet apart.

Question 17. How are they attached to line?

Answer. One side is attached to a line wire and the other side of gap is grounded. A fuse is placed in the ground wire. Each line wire has its own horn.

Question 18. How do they work?

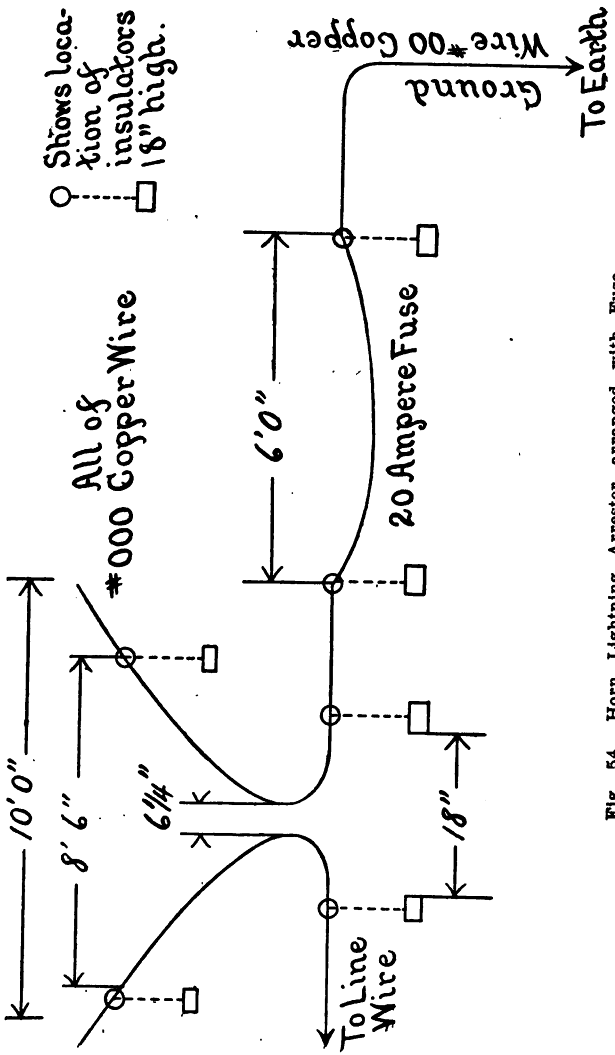


Fig. 54. Horn Lightning Arrester arranged with Fuse.

Answer. The discharge jumps across the gap forming an arc. The heat of the arc causes it to rise and as its ends are in the horns it is stretched out long and thin. This cools the arc down and it goes out. While the arc holds the charge on the line runs across it to the earth.

If the arc does not go out the normal current on the line flows across the arc and blows the fuse. The fuse is made very long so that an arc cannot jump across between the terminals which hold it.

Question 19. What are the advantages of the horn arrester?

Answer. Fairly cheap. They cannot get out of adjustment and discharge at wrong pressure. They cannot produce an accidental ground by getting out of repair or through defects in manufacture. They are mechanically strong and will stand the most severe strokes.

Question 20. What are the objections?

Answer. Any time they discharge the line the fuse may blow. The arrester is then useless until fuse is replaced.

The discharge is a vicious arc which sends a surge through line.

Some engineers think the surge is worse than the original trouble.

Question 21. What is the general opinion about them?

Answer. That they are an excellent thing to use at points on the circuit especially exposed to lightning.

Question 22. What are single or side horns?

Answer. As shown in Fig. 55, the ground wire of each pole is extended up beyond the top insulator and a branch run up outside of each side insulator.

This construction is to protect the insulators by allow-

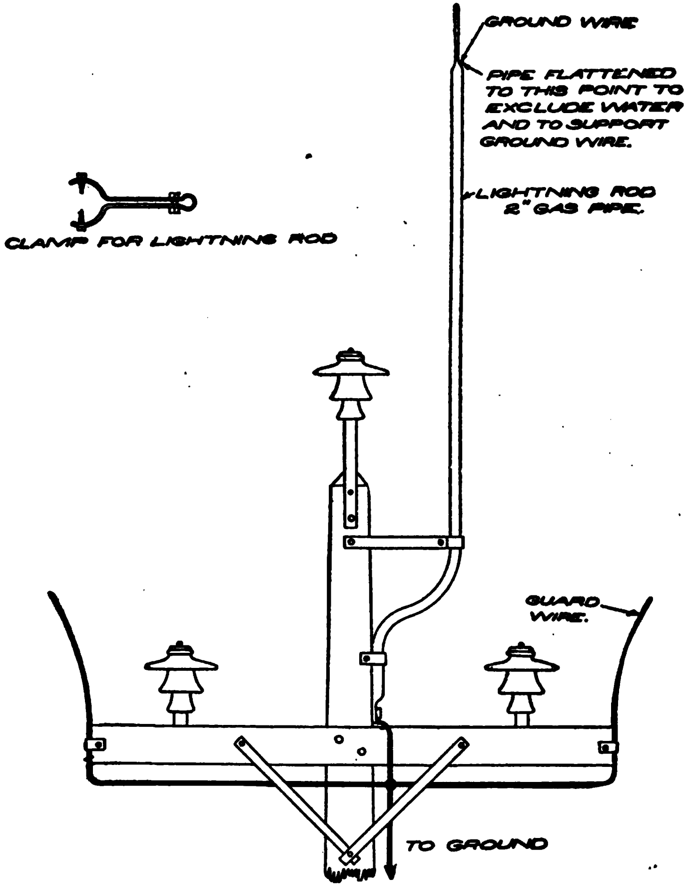


Fig. 55. Side Horns.

ing the discharge to jump to the ground wire instead of flashing around insulator to the cross arm.

This Fig. does not show a ground wire strung from pole to pole.

But horn arresters and side horns can be installed whether there is a line ground wire or not.

Side horns are installed at every pole.

Question 23. What is the lowest voltage used on transmission lines?

Answer. 22000 volts, because at lower voltages the wires have to be so large that expense is too great.

MAINS, FEEDERS.

Question 24. What is the highest voltage used on mains and feeders?

Answer. 11000 volts. Any voltage higher than this needs such special protection, that it should be run on a high pole line, off to one side of the right of way.

The mains from power house or the feeders from substations to the third rail or trolley wire can be run at 11,000 with safety.

Question 25. How should mains and feeders be protected?

Answer. When on pole lines an arrester every half mile is the best practice. When underground, one at each end of the section.

Question 26. Are choke coils used with these line arresters?

Answer. No. Choke coils are only used with station arresters.

Unless an arrester is protecting machinery or instruments no choke coil is used.

LESSON 9.

LIGHTNING ARRESTERS.

AUXILIARY APPARATUS.

Question 1. What is a choke coil?

Answer. It is a coil specially designed to insert in a line between the apparatus to be protected and the lightning arrester.

Question 2. How are they made?

Answer. For low voltage they are simple coils of insulated wire mounted on a slate bases as shown in Fig. 56.

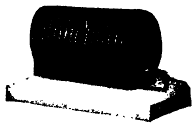


Fig. 56. Low Voltage Choke Coil.

For high voltage (over 600) the wire is bare and the turns are wound in an hour glass fashion, so that air forms the insulation between turns.

Question 3. How do choke coils act?

Answer. A surge or stroke encountering a choke, reactive, or kicking coil in its path is momentarily held back,* practically stopped. The coil then begins to conduct the charge. It will be seen that the choke coil offers

*Throttled, choked off, kicked back, are some of the terms used.

protection for an instant only, but during this time the arrester on the line side of the coil can free the line of the charge.

The damming up of the surge by the choke coil produces an enormous pressure which helps to force the charge through the arrester.

Question 4. What is the objection to a choke coil?

Answer. It has resistance, and so wastes energy, it will also retard a little the flow of the normal current. In order to prevent their interference with normal operation they are large and expensive.

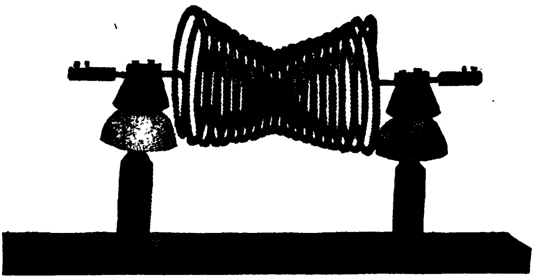


Fig. 57. Hour glass Type of High Voltage Choke Coil.

Question 5. What are the advantages?

Answer. They increase the protection offered by the arrester and even if arrester fails to act the choke coil protects to some extent by causing a side flash on the line where damage is less expensive than should it occur in the station.

Question 6. How are lightning arresters installed?

Answer. They are placed in between line and ground and the two arresters which are attached to the line wires at a certain point are all connected to the same ground

wire, so that there may be a free discharge between line and line, as well as between line and ground.

Question 7. What precautions must be taken when installing arresters in buildings?

Answer. The National Electric Code gives the following rules for the construction and installation of arresters in buildings:

1. Lightning arresters must be mounted on non-combustible bases, and must be so constructed as not to maintain an arc after discharge has passed, and must have no moving parts.

[The arrester shown in Fig. 45 has been tested and approved by the National Board of Fire Underwriters although it has a moving part.]

2. Must be attached to each side of every overhead circuit connected with the station.

It is recommended to all electric light and power companies that arresters be connected at intervals over systems in such numbers and so located as to prevent ordinary discharges entering (over the wires) buildings connected to the lines.

3. Must be located in readily accessible places away from combustible materials, and as near as practicable to the point where the wires enter the building.

Station arresters should generally be placed in plain sight on the switch-board.

In all cases, kinks, coils, and sharp bends in the wires between the arresters and the outdoor lines must be avoided as far as possible.

4. Must be connected with a thoroughly good and permanent ground connection by metallic strips or wires having a conductivity not less than that of a No. 6 B. & S.

copper wire, which must be run as nearly in a straight line as possible from the arresters to the earth connection.

Ground wires for lightning arresters must not be attached to gas-pipes within the buildings.

It is often desirable to introduce a choke coil in circuit between the arresters and the dynamo. In no case should the ground wire from a lightning arrester be put into iron pipes, as these would tend to impede the discharge.

Question 8. How should arresters be grounded?

Answer. For station arresters there are many ways of getting a good ground.

Copper sheets approximately 1/8 inch thick and of 4 to 6 square feet surface are suitable. A piece of cast iron of large surface, with brass or copper plug tapped into it for connections, is preferable. Cast iron does not waste away as rapidly, and, when completely oxidized, still affords a good ground path.

The ground wire must be carefully riveted or soldered to the plate and the connection coated with a preservative paint.

The plate should be buried deep enough to be in damp soil the year through. The bottom of the hole should be covered with broken charcoal, coke or carbon to a depth of 2 or 3 inches. After the plate is put in position, it should be covered with another layer of charcoal, coke or carbon, and the hole filled with earth. It is well to use running water to settle.

Ground connections may be made to plates placed in the mud at the edge of a stream. Where water or gas pipes are available, the ground wires should be soldered to a brass plug screwed into the pipe in addition to the

connection with the ground plate provided. In grounding arresters on electric railway circuits, a connection with the rails, as well as with the ground plate, should always be employed.

Where an iron pipe is used to protect the ground wire, the wire should be soldered to a cap on the upper end of pipe. This avoids the choking effect of the pipe upon a wire passing through it.

For pole arresters a cheaper arrangement is necessary. The ground pipe is perhaps the best.

Fig. 58. Ground Pipe Fittings.

These may be driven into the earth, or if the soil will not permit driving, a hole may be dug at the foot of the pole to receive same. The pipe should extend upward along the pole for eight to twelve feet above the ground, to prevent cutting or removing the wire, and the ground wire soldered to a cap on the upper end of the pipe. The pipe should extend eight or ten feet below the surface where it will be in damp earth the year round.

For this purpose are manufactured the fittings illustrated in Fig. 58. These are tapped for use with ¾ inch iron pipe and consist of the brass cap GP 100, with lug

for soldering in ground wire from the arrester. GP 101 is a brass coupling for connecting upper and lower sections. (It being more convenient to drive an 8 or 10 feet length and then couple on another length, than to drive a 16 or 20 feet length.) This brass coupling GP 101 is also provided with a lug for soldering in wire to rail, when used on electric railway circuits. The driving point GP 102 is of malleable iron, with dipped galvanized finish.

Fig. 59. Ground Plate for Pole Arresters.

The pipe may be driven by placing an iron cap on upper end, to protect the threads, or the method used by well-drivers may be used to advantage. This is to start the hole, fill with water and "churn" the hole to the required depth with the pipe. This method is of particular advantage where the soil is very hard.

In Fig. 59 is shown a cast iron plate, 12 inches in diameter (total surface 450 sq. in.), with hole near edge tapped for ¾ inch pipe. This plate may be used in place of the driving point and should be buried at the foot of pole, and the necessary length of pipe attached.

It may be buried at the bottom of pole before the pole is set, but if this is done, it should be made certain that the surrounding soil will be damp the year through.

In electric railway circuits the rails should be connected to the ground wire as is shown in Fig. 60.

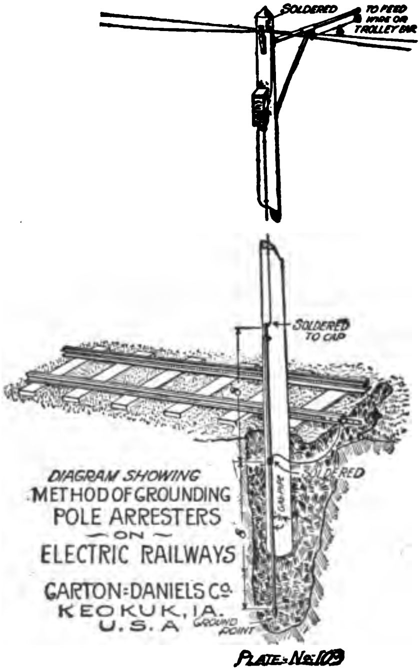


Fig. 60.

The rail alone will not suffice, as it may be up on a rock road-bed, or buried in cement or a soil that does not provide a low resistance path for the lightning. With a connection to both rail and ground point, any danger due

to difference of static potential between rail and earth is avoided. Should either one of the connections be broken or fail from any cause, the other one probably will be in order and afford a degree of protection.

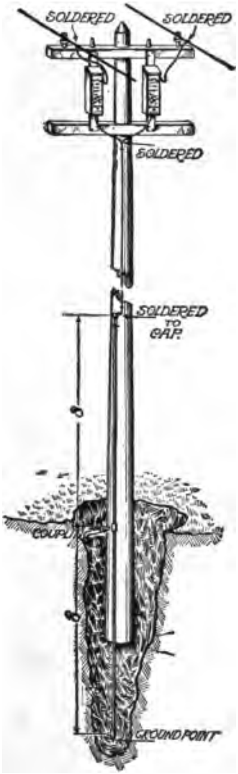


Fig. 61.

Fig. 61 shows manner of grounding a two wire or ungrounded circuit.

All ground wires should be No. 6 gauge or larger.

Question 9. What inspection is necessary for lightning arresters?

Answer. Frequent inspection (once a month) and cleaning with a bellows for dust is necessary.

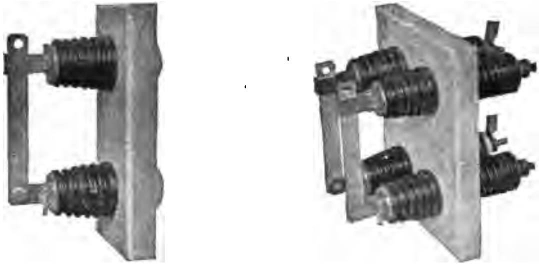


Fig. 62. Low Voltage Arrester Disconnecting Switches. Single for Railroad work. Double for Electric Lighting.

Question 10. Is there not danger in the men inspecting the arresters?

Answer. Disconnecting switches as shown in Figs. 62 and 63 are installed in places where some other switch will not serve to disconnect the arresters.

Fig. 63. High Voltage Disconnecting Switch for Arrester.

LESSON 10.

MAGNETISM.

INTRODUCTION.

The natural magnet has been known for ages. The Egyptians and Greeks in their writings long before the Christian era mentioned that a certain mineral attracted iron and steel. They also knew that a piece of steel being rubbed or rather stroked with the mineral, acted

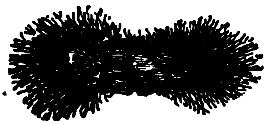


Fig. 64. Natural Magnet: A piece of Magnetite or Black Oxide of Iron.

just as if it had become a piece of the mineral. Fig. 64.

Who first discovered that the mineral would point to the north, we do not know, but in the year 1200 A. D. Arabs brought compasses to Europe.

The mineral was called lode stone because it was a leading stone i. e. it lead you to the north.

The name magnet was also given to it because most of it came from a part of Greece called Magnesia.

Besides the quantity in Greece large quantities of magnetite are found in Sweden, Spain, also in states of Arkansas and New Jersey.

Question 1. What is a magnet?

Answer. A magnet is a piece of material which will turn into a north and south position when suspended so as to be free to turn.

Question 2. Can it be any material?

Answer. No. It can only be of iron, steel or nickel, or a few other substances which are feebly magnetic.

Question 3. But the mineral mentioned is a magnet?

Answer. Yes, because it is iron ore.

Question 4. Then copper, zinc, etc., cannot be magnetized?

Answer. No.

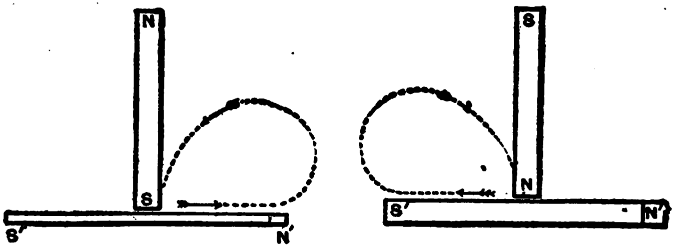


Fig. 65. Making a Magnet by use of a Permanent Magnet.

Question 5. How can a magnet be made?

Answer. Produce two pieces of Jessup's steel about 6x¼x¼ or 12x1x3-16 inches. Machinery steel, manganese steel, and some cast steels are useless. Heat them moderately bright red and plunge sidewise and edgewise into water or oil. They will become very hard and brittle, or as we say "glass hard."

1. Lay one down on the table and stroke one-half of the bar from the center out to the end. Fig. 65. Do this ten times with the S-pole of a permanent magnet,

and turning the bar over repeat this on the same end. You now have an N-pole. Then using the N-pole of the magnet stroke the other end of the bar in the same manner. You now have the complete magnet with two strong poles. You have made 40 strokes in all and you need that many, but sitting there stroking for a 100 or more times is wasted energy, for the bar soon becomes saturated and will take up no more magnetism. Then treat the second piece in the same way. Always make two at the same time and keep them by laying them with an N and an S-pole at the same end of the box, separating the magnets lengthwise by a strip of card board, and placing a strip of tinned iron or strap iron across the ends. Laid away separately or with two N-poles side by side they lose strength. Fig. 66.

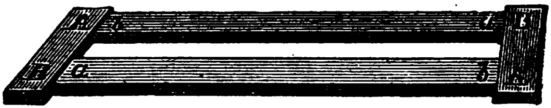


Fig. 66. Two Bar Magnets with Keepers across ends. A represents north pole and B, south pole.

As shown in Fig. 67 wrap insulated wire around the bar or on a spool in which the bar will be placed. Connect the wire to a battery, dynamo or electric light circuit, and while the current is flowing in the coil tap the bar with a hammer. Stop tapping before the current is turned off. No one unskilled in the handling of electrical machinery should do this, as one can cause considerable damage to himself and to the electrical wiring. Correct management of this process will produce the strongest possible magnet.

Question 6. Do magnets need to be handled carefully?

Answer. Yes. Dont: Heat, drop hammer, or file your magnet, for it will lose strength.

Question 7. How should magnets be kept when not in use?

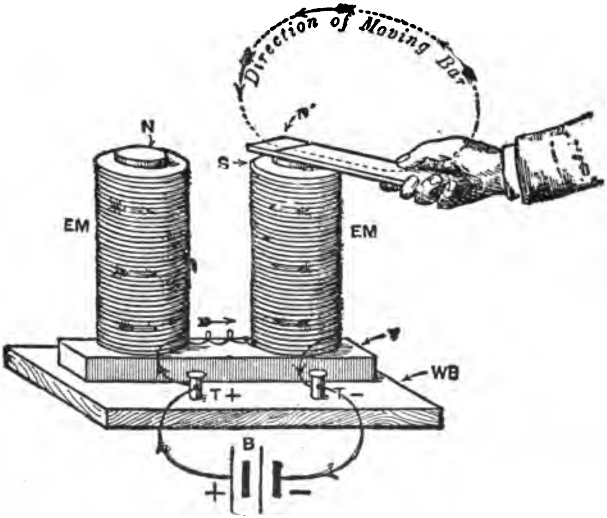


Fig. 67. Making a Magnet by means of an Electro-magnet.

Answer. Bar magnets should be laid side by side, separated by a thin strip of wood, the north end of one and south end of the other at same end. Strips of iron should be laid across the ends so as to touch both magnets as in Fig. 66.

Horse-shoe magnets should have a strip of iron laid across the ends as in Fig. 68.

Question 8. What is a magnetic needle?

Answer. It is a long slender magnet, as compared with its own width and thickness, fitted with a cap in the center so that it may be balanced on a pivot or hung from a thread. This allows it to turn freely. Fig. 69.

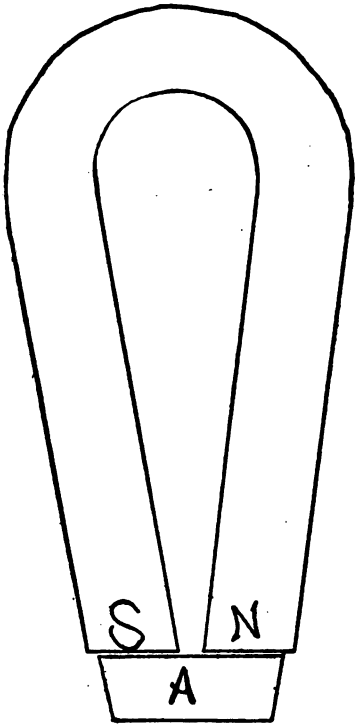


Fig. 68. A Horseshoe Magnet with its Keeper or Armature A.

Question 9. How may you determine whether a bar is a magnet or not?

Answer. To decide the question whether the bar in our hand is a magnet or not we put it to test in this way.

Remember, however, that should the bar be of wood, fibre, copper, zinc, etc., there is no need of a test since only steel, iron and nickel have enough magnetism in them to be worth calling magnets.

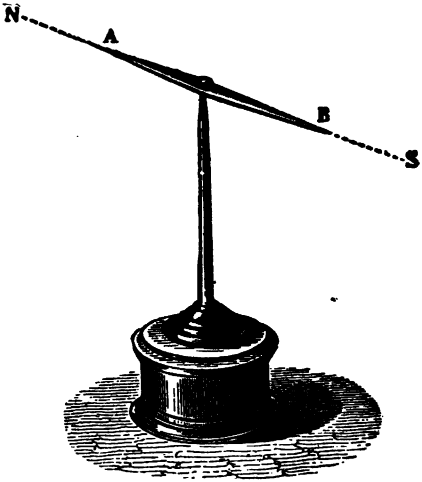


Fig. 69. Magnetic Needle.

1. Bend a stirrup of copper or brass wire and suspend the bar in it. Hang the whole by a single thread that has been untwisted and soaked in water long enough to take out all the twist. If the bar persistently returns to the north and south line after being moved out of it; then it is a magnet.

2. As a further precaution procure a magnet needle from some dealer and suspend it as in Test 1. If it satisfies this test proceed to take your bar in hand and cautiously approach one end of the magnet. Should it at-

tract it reverse the piece in your hand, and it should now repel. If it does all right, it is a magnet; if it does not, it is not a magnet.

Question 10. Why is the repulsion test more important than the attraction?

Answer. Because any piece of iron or steel will be attracted to a magnet but only a magnet will ever be repelled.

Question 11. Is this rule absolute?

Answer. Hitherto only iron, steel and nickel have been mentioned as capable of being made magnets. Cobalt and manganese possess, limitedly, the same capability. Metals of this character are called Paramagnetic, and are attracted by the poles of magnets. There are other substances, among which are phosphorous, bismuth, zinc and antimony, which act in a contrary manner, being repulsed by magnets. These substances are known as Diamagnetic substances.

This repulsion is so weak that it can never be mistaken for the repulsion of a magnet by a magnet. Furthermore, these diamagnetic metals are repelled by either end of a magnet.

Question 12. What are the poles of a magnet?

Answer. The ends of a magnet are called its poles.

Question 13. How are the poles named?

Answer. The end which points to the north geographical pole is called the north pole of the magnet, the other end is called the south pole of the magnet.

Question 14. How are the poles marked?

Answer. The north pole with an N or a line cut in the steel, the other end is left unmarked.

Question 15. What is the polarity of a magnet?

Answer. By polarity we mean the nature of the mag-

netism at a particular point, whether it is north or south magnetism.

Question 16. What are consequent poles?

Answer. In long magnets extra poles may be found besides the poles at the ends. These extra poles always come in pairs. Such a magnet is shown in Fig. 70.

Question 17. What rule gives the results of magnetic attraction and repulsion?

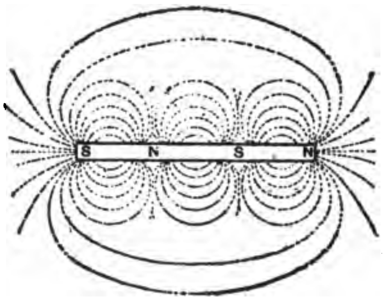


Fig. 70. A Magnet with Consequent Poles.

Answer. Either pole of a magnet attracts a magnetizable metal. Like poles repel, unlike poles attract.

If you take a magnet a foot long and brutally jab it at a tiny compass needle this rule may not work and the reason is this: The great power of the large magnet sweeps out the private magnetism of the compass and replaces it by magnetism whose poles are just the opposite to that which was formerly there. When the poles are reversed, then where there was repulsion there will now be attraction.

Question 18. But the end of the magnet which points to the north geographical pole is called the north pole of the magnet?

Answer. Yes, for convenience we do say this and then to get out of the difficulty we say that the south magnetic pole of the earth is up at the north geographic pole.

It must be definitely understood that when we speak of the "magnetic north pole" we mean that spot on the earth's surface which exhibits "south polarity."

When we speak of the north pole of a magnet we can avoid any confusion by saying the "north seeking pole."

Question 19. Has the earth polarity?

Answer. Yes, the region around the north geographic pole has south pole magnetic polarity. Around the south geographic pole there is north pole magnetic polarity.

Question 20. Is not the north magnetic pole exactly at the north geographic pole?

Answer. No. Standing in Chicago the compass points a little east of the geographic north. At San Francisco it points 16 degrees* east and in New York 10 degrees west of the true north.

Question 21. Why is this?

Answer. The magnetic north pole is about 1400 miles south of the north pole and looking from New York about 10 degrees west of it. Why the magnetic pole should be here instead of at the north pole we do not know.

Question 22. Are there any places where the compass points to the north pole?

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*If the circumference of any circle is divided into 360 equal portions, each is called a degree. A right angle embraces 90° (° is abbreviation for degree).

All degrees are not of the same size unless the circles happen to be the same size.

Answer. Yes. There is a ring around the earth where the compass points north. This ring is an irregular line. In the United States, Charleston, S. C., the east end of Tennessee, Columbus, Ohio, and Lansing, Mich., are on this *Agonic* line. It crosses Russia, Persia and Australia.

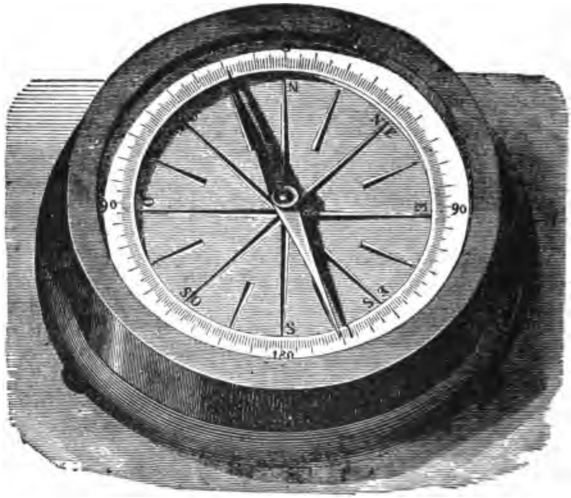


Fig. 71. A Compass marked with Degrees as well as the Points of the Compass.

Question 23. Is the magnetic north pole fixed?

Answer. No. In 1580 in London the needle pointed 11° east of north, it gradually swung over till in 1657 it pointed true north, it kept on till in 1816 it pointed 24° west of north and then it swung back so that in 1907 it points about 15° west of north. It seems as if it took about 320 years to make a complete swing.

Question 24. What name is given to this peculiarity of the compass?

Answer. It is called the *Declination* of the compass. It may be easily remembered because the compass declines to point true north.

Fig. 72. Dipping Needle.

Question 25. What is a compass?

Answer. The usual compass is a magnetic needle suspended over a card bearing the names of the points of the compass and sometimes the 360° of the circle are marked out. Fig. 71.

Question 26. Why do home made compasses balance badly? One end seems too heavy.

Answer. Near the equator of the earth a needle may be balanced and then magnetized, but in other places if the needle is balanced and then magnetized one end of the needle will dip. Fig. 69 shows this. If the needle is mounted so that it can turn with perfect freedom vertically as in Fig. 72 it will in Chicago incline from the horizontal line about 70°.

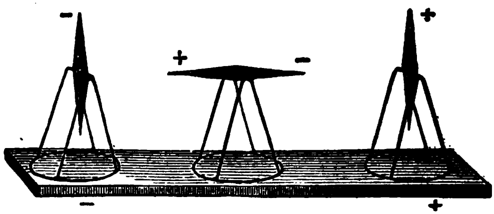


Fig. 73. Showing Dip or Inclination of Needle at Magnetic north pole, Magnetic equator, Magnetic south pole.

Question 27. Is this Inclination of the needle the same all over the world?

Answer. No. In Fig. 73 is shown the *Dip* or Inclination of the needle at the magnetic north pole, magnetic equator and magnetic south pole. As you leave the equator going either way the dip increases until you reach the poles.

Question 28. How is the dip neutralized in compasses.

Answer. By balancing the needle after magnetizing, or if the compass must be used all over the world by attaching a tiny sliding weight.

North of magnetic equator the weight is put on south end of needle and south of it it is put on the north end of needle.

Question 29. What is the magnetic equator?

Answer. It is an irregular line running around the world, being north of the geographic equator on Atlantic ocean and south of it on Pacific ocean. Along this line there is no dip to the needle.

Question 30. Do you consider the earth a huge spherical magnet?

Answer. Yes. These experiments tend to show that the earth is a magnet, for it magnetizes objects.

Experiment 1. Procure a small pocket compass, and hold this so that the needle will move freely, against an iron stovepipe. Raise and lower it past the joints in the pipe, and as a rule the action of the needle will show that there is a change of polarity at each joint, the ends of the needle being alternately attracted in passing.

Experiment 2. With the same compass explore the polarity of any permanent piece of iron, such as a balcony, an iron safe, a gas or water pipe which lies in a north and south position, and it will generally be found that the north and south extremities between joints will show different polarities.

Experiment 3. Explore the polarity of a street car rail lying in a north and south street. Its polarity will be found to be lengthwise of the rail. Now try a rail lying in an east and west position, and it will generally show a polarity at right angles to the length of the rail—the north side will show one polarity, while the south will show the other.

Experiment 4. Take a fine cambric needle from a package which has been lying in a north and south position, and drop it carefully on a glass of water. In the majority of cases, if properly handled, it will float, and generally show polarity by settling in a north and south position.

Experiment 5. If now, while this needle is lying on the surface of the water we approach it carefully with the compass, one pole will be attracted, and the other pole will be repelled. That is, the two ends of the compass needle will repel the like ends of the floating needle, but will attract the dissimilar ends. This experiment may be made still easier by floating the needle with a tiny bit of cork through which it has been thrust.

Question 31. Can the earth's magnetism be shown in any other way?

Answer. Yes, if a bar of hard steel or even hard iron and some iron filings are procured.

Hold the bar level in an east and west position and strike one end a smart blow with a hammer. Now dip it in the iron filings and we shall find it has little or no magnetism, at least in its length. Now point it downward at an angle corresponding to the latitude where you are, so as to point to the actual north magnetic pole as nearly as possible, and strike the end of the bar, as before. You will find that the bar has acquired a quite perceptible amount of magnetism; that either end will attract the iron filings, tacks or other bits of iron, and that the phenomena of attraction and repulsion will be shown by bringing it near the compass needle.

Now, having marked the end which attracts the south end of the needle with paint or chalk as the N pole, we again point it to the north pole of the earth, but in a reversed position, and strike it again as before. On testing for magnetism we will find that the particles of iron adhere as before, but what we marked as the N pole of our magnet has become the S pole, and repels the end of the needle it attracted before.

LESSON 11.

MAGNETISM—CONTINUED.

Question 1. For the experiment in A. 31 of Lesson 10 why is it necessary to take hard steel to get best results?

Answer. We know that wrought iron becomes a magnet readily, steel castings are easily magnetized, cast iron less easily and hard steel is the most difficult of all to magnetize. The more difficult it is to magnetize a substance, the better it retains its magnetism. If you want a permanent magnet use hard steel. If you want a temporary magnet use iron or steel castings.

Question 2. Do you mean steel castings or cast steel?

Answer. I mean steel castings which are made of Bessemer steel. Cast steel is a high grade steel which is expensive and is used for tools, etc.

Question 3. Does magnetism permeate some metals better than others?

Answer. Yes. We say that some metals have greater permeability than others.

Wrought iron is the most permeable, cast iron the least permeable, of the cheaper metals. Hard steel has small permeability.

Question 4. Do some metals retain magnetism better than others?

Answer. Yes. The retentivity of wrought iron is least, and that of cast iron the greatest of the commonly used metals. Hard steel has great retentivity.

Question 5. How can you explain the facts of different permeability and retentivity?

Answer. We know the following facts, and from these we have thought out an explanation which we think is correct.

Facts:—

(1) The softest iron is the most permeable.

(2) Soft grey cast iron has greater permeability than hard white cast iron.

(3) The harder the steel the less permeability.

(4) When a bar of iron or steel is suddenly magnetized there is a faint click and the bar lengthens slightly. If magnetized and demagnetized rapidly the clicks will merge into a hum or buzz. Keeping this up for a length of time heats the bar.

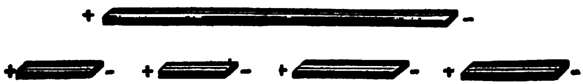


Fig. 74. The result of Breaking a Magnet is Several Short Magnets.

(5) Pounding or jarring a permanent magnet weakens it. So does heating it red hot.

(6) If a magnet is broken, each piece is a perfect magnet with two poles. No matter into how many pieces you break a magnet, each is still a magnet. See Fig. 74.

(7) If a thick piece of steel is magnetized and then laid in nitric acid for some time, when the outer surface has been eaten off, a test for magnetism will show that the bar has lost almost all its polarity. Magnetism is evidently only skin deep.

(8) Four bars 6 x 1 x ¼ inches magnetized and

bound together make a much stronger magnet than one bar 6 x 1 x 1 magnetized from as powerful a source.

Theory:—

From the above facts we have concluded that a piece of iron or steel is not solid but comprised of innumerable small particles which are each a perfect magnet.

In ordinary iron or steel these are all jumbled up as in Fig. 75, and do not show any magnetism.

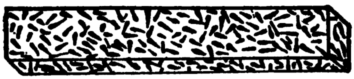
A 

Fig. 75. A Bar of Iron Unmagnetized.

There being about as many north and south poles pointing the same way, they neutralize each other.

Now suppose this bar be stroked by a magnet as in Fig. 65. The influence of the magnet will be strongest at the surface and weaker as it penetrates. In fact, after 1/8-inch under surface the action is practically nothing.

B 

Fig. 76. A Bar of Iron while magnetized.

What this magnet does is to pull all the little particles around into line with the north poles pointing one way and the south poles the other. This movement of the particles causes a slight noise if they move all at once, but the gradual movement due to the stroking does not produce a sound that we can hear. If the rod is iron it lengthens a tiny bit; if it is a nickel rod it shortens a little (about 1-700000 of its own length).

The rapid magnetizing and demagnetizing pulls them around so fast that the internal friction heats the bar.

Fig. 76 shows the bar with the particles all in line, and as each particle is a miniature magnet, Fig. 77 shows why the whole bar becomes a magnet.

If now the magnet be pounded the vibrations shake up the particles and they get jumbled up and the bar ceases to show its magnetism.

The harder the iron or steel the more difficult it becomes to pull the particles into line and make a magnet.

In the same way once magnetized the better they stay in position.

Fig. 77. Internal Structure of a magnetized Bar.

Very soft wrought iron may be magnetized easily, but as soon as the magnetizing force is removed the particles slip back to the jumbled condition.

A glass tube filled with cast iron filings may be magnetized by a coil of wire. On examination the filings will be seen all arranged, end for end.

Handled carefully it will act as a magnet, but when shaken so as to jumble up the filings it loses its polarity.

You notice we do not say it loses its magnetism, for it does not. It ceases to have magnetic poles at each end, i. e., it has lost its polarity.

When we say demagnetize a bar, it would be more accurate to say depolarize.

We use this word, however, for a different thing and say demagnetize, for every one understands what we mean.

Question 6. Will a magnet floated on water by corks be drawn to north or south?

Answer. No. The force that the earth exerts on a magnet will only turn it into the north and south line.

The poles of the earth are so far away and the magnet so small that the distance between the two poles of the magnet is practically nothing as compared with the distance from magnet to either pole.

The south magnetic pole of the earth attracts one end and repels the other end of the magnet. The forces are equal because distances are equal. The same thing happens at other end of the magnet. The result is no motion.

Question 7. Can the earth's tendency to turn a compass needle be neutralized?

Answer. Yes. Take a bar magnet and hold it high above and parallel with the compass needle. Let its north pole point in the same direction as the north pole of the compass needle.

Slowly lower the magnet until the compass needle starts to waver. If the magnet is fastened in this position the compass needle will stay in any position it is placed.

Question 8. Is this of any practical use?

Answer. Yes. If surrounding iron objects or magnetized things are interfering with the earth's effect on the compass, then by means of extra magnets these disturbing influences may be neutralized and the earth's magnetism alone left free to turn the compass.

This must be done with compasses on iron or steel ships.

Question 9. What is meant by magnetic force?

Answer. The force exerted by one magnet on an-

other to attract it or to repel it, or to attract iron filings or pieces of iron is termed magnetic force.

Question 10. Does this force act all over the magnet?

Answer. There is almost none in the center, and most at the ends. Plunging the end of a magnet into a box of iron filings shows this.

Question 11. What are the relative magnetic forces at different points from the center to the end of a magnet?

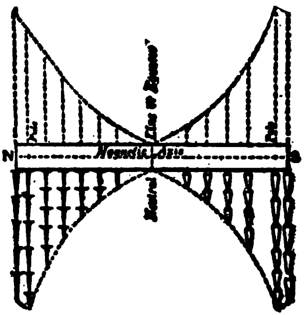


Fig. 78. Strength of Magnetism as roughly Tested by Lifting Power.

Answer. Fig. 78 shows approximately the magnetic force at different points. It shows that the pole of a magnet is not at the tip end, but a little way back.

An accurate test of a six-inch bar magnet has shown these results:

Location of Point.	Magnetic Strength.	
Center	None	
½″ away	9 units	
1	20	
1½	33	Other end gave
2	48	same results
2½	65	
2¾ Pole	84	
3 Tip end	80	

Question 12. What are the magnetic lines of force?

Answer. These words are used in several different ways. The word magnetic is usually dropped for the sake of shortness and "lines of force" spoken about. Engineers usually say "lines."

(1) The magnetic force of a magnet seems to lie along certain lines and these lines are called "lines of force." Perhaps "direction of force" would be a better name.

(2) When a magnetic pole exerts a certain force of repulsion on the same named pole of a magnet of equal

Fig. 79. Lines of Magnetic Action around a Bar Magnet.

strength we say that there are 10,000 "lines of force" to the square inch in that magnet pole. If it exerted twice that force we would say there were 20,000 lines to the square inch.

Perhaps "units of force" would be a better name for this.

It has been proposed to drop the expression "line of force" when used as "units of force," and say 10,000 gausses. Whether this word will be adopted or not remains to be seen.

Question 13. How may the direction of force be ascertained?

Answer. Place the bar magnet on a table (Fig. 79) and lay over it a sheet of glass.

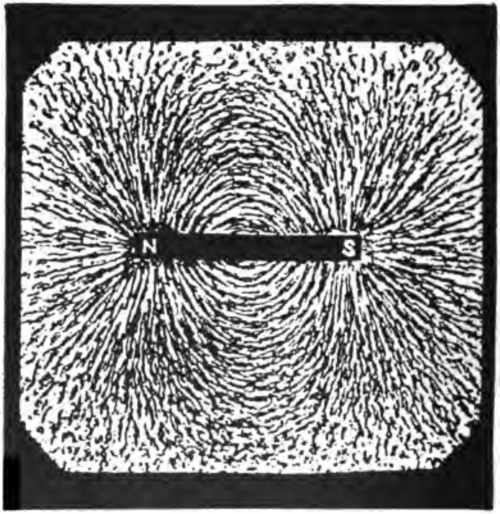


Fig. 80. The Magnetic Field of a Bar Magnet as shown by Iron Filings.

Lift iron filings over the glass and tap very gently. The filings will arrange themselves and show the direction of the magnetic force at all points.

Many different combinations of poles should be tried. Figs. 80 and 81 show two magnetic spectrums.

Question 14. What is a magnetic field?

Answer. The space around a magnet under its influence is called a magnetic field.

The spectrum made with iron filings shows the directions of the magnetic forces in the magnetic field.

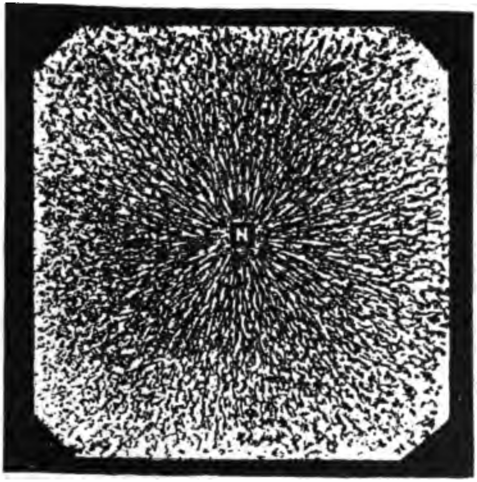


Fig. 81. The Magnetic Field of a Magnet Pole. Magnet at Right Angles to Observer.

Question 15. What is magnetic induction?

Answer. When a piece of soft iron free from magnetism is placed in a magnetic field it becomes a magnet by induction.

Fig. 82 shows this. The part of the iron under the north pole of the magnet becomes a south pole.

It may be difficult to find a piece of iron which is not slightly magnetized.

Question 16. How can you demagnetize?

Answer. Heat to a cherry red and cool very slowly. The piece may be now hardened and tempered and no magnetism will appear.

Question 17. Explain magnetic induction more fully.

Answer. (1) Hold a magnet horizontally and attach to its north pole a soft iron nail. To this nail at-

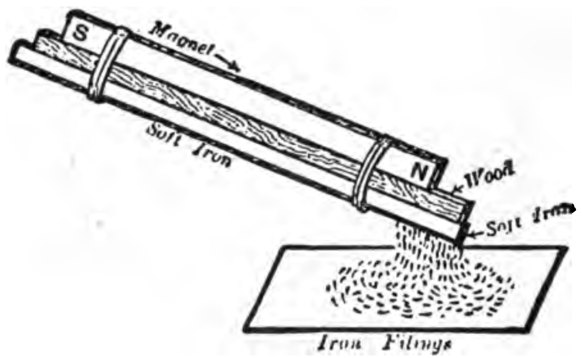


Fig. 82. The Induction of Magnetism in Iron without Contact.

tach another until three or four are adhering to the magnet. The end of the first nail which is in contact with the north pole of the magnet becomes a south pole by induction. This temporary polarity of the first nail acts on the other, and so on down the line of nails. The polarity of the nails is shown by small letters on the left side of the nails in Fig. 83.

Now slide the south pole of a similar magnet (the other one of the pair) over the north of the first magnet.

This magnet will act inductively on the nails, and the

small letters on the right side of the nails show the polarities induced.

The result of the two effects is to render the nails neutral, and they drop off.

(2) Attach nail to one magnet as before and then as in Fig. 84 place the other magnet below. The effect of the upper magnet is the same as before. The lower magnet acts inductively on the nails, but the south pole of the magnet acts on the lower end of the last nail, so that the polarities induced are the same as those induced by the upper magnet. The result is a stronger magnetic

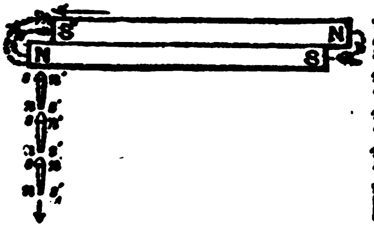


Fig. 83. Demagnetizing Inductive Effect of Unlike Poles.

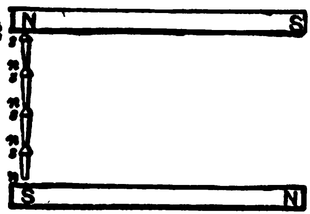


Fig. 84. Increased Magnetizing Effect of Unlike Poles.

action than before. It will be seen by experiment that more nails can be supported.

Only one set of small letters is used because both magnets induce the same polarities.

(3) If, as in Fig. 85, the two magnets are held together, we have the same effect as if a stronger magnet were used.

(4) Placing the second magnet below as in Fig. 86 results in demagnetizing the nails. The left-hand letters show effect of upper magnet, the right-hand letters

the effect of the lower magnet. Net effect, no magnetism.

A slightly different explanation of these four facts will be given in Lesson 13. This explanation will be no better, but merely telling the same thing in a different way.

Question 18. Is there any material which will insulate from magnetism?

Answer. No. Deflect a compass needle slightly by a bar magnet. Slip in between them thick sheets of cardboard, copper, wood, glass, rubber, in fact anything but iron or steel, or perhaps a thick slab of nickel, and the deflection of the needle is not affected.

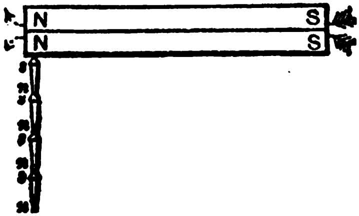


Fig. 85. Increased Magnetizing Effect of Like Poles.

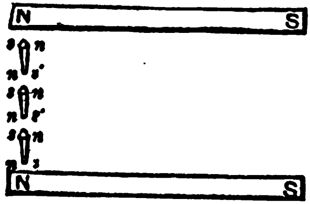


Fig. 86. Demagnetizing Inductive Effect of Like Poles.

This shows that magnetism passes through anything.

Question 19. What would be the result if a piece of iron or steel were placed between needle and magnet?

Answer. If a sheet of steel, iron (wrought or cast), is interposed the deflection will become much less.

Question 20. How do you explain this?

Answer. It seems that everything conducts magnetism equally well, but perhaps equally poorly would be more accurate, except iron or steel. Therefore the magnet does not care or even know that something else

has been put in place of part of the air through which it must send its force or effect. But when the iron is put in place it is so much better a conductor that the magnetic effect prefers the easy path through the iron off to the side, instead of going on into the air beyond. Hence only a little effect passes on to the compass. Indeed, if the iron screen were thick enough in proportion to the strength of the magnetism present, none would pass through.

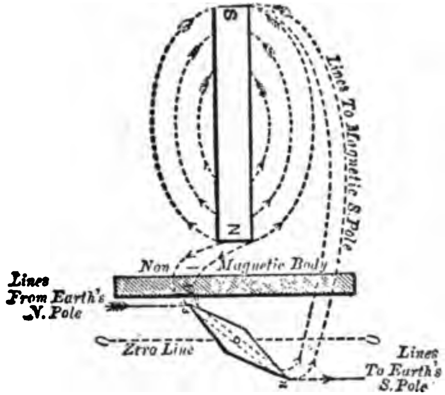


Fig. 87. Needle Deflected Through a Non-Magnetic Body.

These effects are shown in Figs. 87 and 88. The lines along which the magnetic force acts are also shown.

Question 21. Are there any practical uses of the screening action?

Answer. Yes, several uses are made of it.

(1) Advantage is taken of this fact by putting an extra hunting case of soft iron on a watch to screen it from the magnetism of electrical machinery.

(2) Measuring instruments used on switchboards or near dynamos are enclosed in heavy cast-iron cases.

(3) Galvanometers are sometimes surrounded by a cylinder of wrought iron, or a piece of heavy iron pipe. A small hole is cut in the side, so as to observe the deflection of the needle.

Question 22. To what practical use are permanent magnets put?

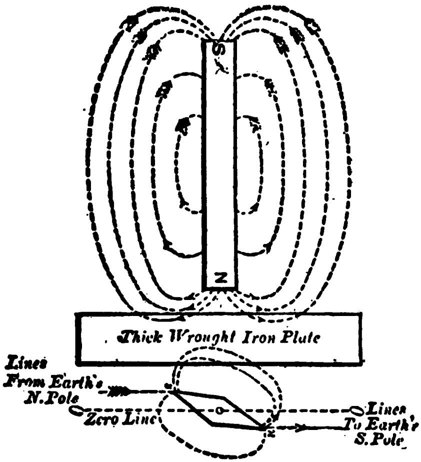


Fig. 88. Needle Screened from Action of a Magnet by a Magnetic Body.

Answer. They are used in the receivers of telephones; in magneto bells for telephone calling and general signalling; in the magnetos used for ignition purposes in gas, gasolene and oil engines; as magnets in measuring instruments.

Question 23. How are magnets named?

Answer. When an engineer or electrician speaks of a magnet he means an electro-magnet; when he says permanent magnet he means a piece of hard steel which has been magnetized. In referring to a piece of iron temporarily magnetized he calls it an armature or a core.

LESSON 12.

ELECTRO-MAGNETISM.

It is well known that all the effects due to a natural magnet or an artificial magnet, can be produced by a current of electricity.

The effects produced by the electric current are so much more powerful than natural magnetism, and the cost is so much less that they are almost universally used.

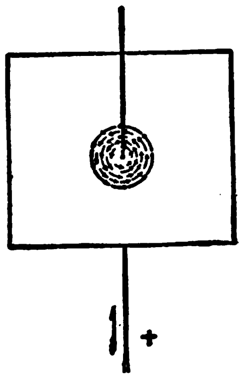


Fig. 89. Magnetic Field due to Electric Current.

Question 1. What is electro-magnetism?

Answer. It is the magnetic effect produced by a flow of electric current.

Question 2. Does a wire carrying current have a magnetic field?

Answer. Yes. Pass a straight wire carrying a large current through the center of a sheet of cardboard as shown in Fig. 89. If iron filings are sprinkled on the board they will arrange themselves in circles around the wire, thus showing the magnetic field.

Question 3. Will the wire affect a magnetic needle?

Answer. Yes. If a small compass be placed on the cardboard and pushed around the wire it will be seen that the needle is being moved by the magnetic action of the current in the wire.

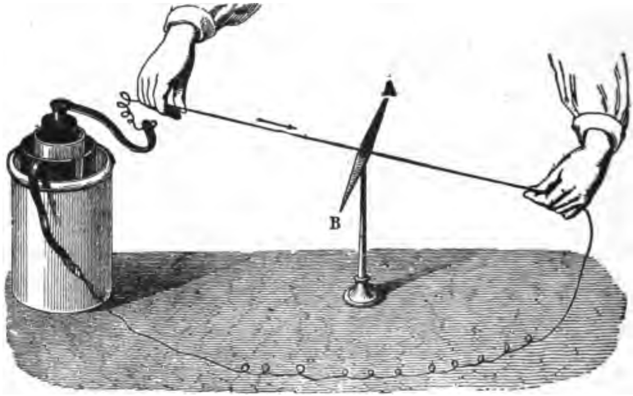


Fig. 90. Action of Electric Current on Magnetic Needle.

It is also easily shown by holding a wire carrying current over a magnetic needle. The needle will be turned and stand at an angle to the wire. Fig. 90 shows this.

Question 4. Does the wire exhibit north and south polarity like a bar magnet?

Answer. No, not like a bar magnet. It moves the magnetic needle in the following way: When the cur-

rent flows from the South to North Over the needle the N-end turns West.

This is called the SNOW rule, so called from the first letters of the important words of the rule.

To test this rule arrange things as in Fig. 91. Turn the cell so that a line through the copper and zinc plates will be north and south, and have the copper plate to the south. Bend your wire circuit into a loop standing vertically in the N. and S. line. Stand behind the zinc plate facing south; put a small compass in this loop with the N. mark on the box pointing to the north.

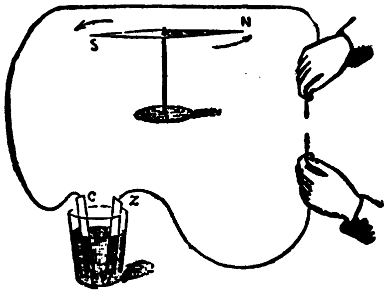


Fig. 91. The S-N-O-W Rule.

If the circuit is *open,* i. e. the dry ends of the plates not touching, and the connecting wires cut and the ends held apart, then the N-end of the needle will as usual point to the north.

Close the circuit by touching the ends of the wire, and the N-end of the compass will move to the west (to your right hand). Since we say the current flows from carbon to zinc plates, this proves our rule correct.

Question. 5. Give a further proof that although the current acts magnetically it does not act like a bar magnet.

Answer. If the wire were a simple bar magnet putting the current under the needle would not change the direction of the deflection, but it does change the direction of the deflection. Further if the wire were like a bar magnet when the current was reversed it would change in polarity and attract the needle holding it in the north and south line, but it does not do this. When the current is reversed it deflects the needle the other way.

Question 6. Why does the current act in this way on a magnetic needle?

Answer. We do not know. The current acts as if it had a paddle wheel of magnetism rotating on the wire as an axle and in the opposite direction to the hands of a watch when the current is flowing towards you.

Standing in the position shown in Fig. 91, when the current is over the needle flowing towards us (north), the part of the *whirls* (paddle wheels) of magnetism on the under side of the wire are turning towards the west and knock the N-end of the needle in that direction, and since the S-end always does the opposite thing it goes east.

But moving the wire under the needle the parts of the whirls on top of the wire are moving east and push the N-end of the needle in that direction.

Fig. 92 shows the magnetic whirls around the wire, and the effect of the SNOW rule. For since the current runs in the opposite direction from the rule, we should expect to find the N-end of the needle move in

the opposite direction. This is exactly what it does. The N-end of the needle moves East.

This may be made into a rule and called the NOSE rule.

When a current flows from North Over a needle to the South the N-end is deflected East.

Question 7. For what is the extra hand in Fig. 92?

Answer. The extra right hand shown in the illustration is another way of remembering the SNOW rule, and is especially adapted to discover in which direction the current flows.

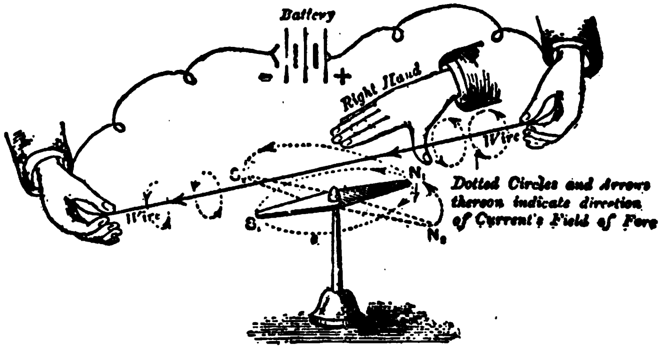


Fig. 92. Action of Current on a Magnet.

Arrange the wire ABOVE *the needle in a N and S line placing the palm of* RIGHT HAND OVER *the wire with the* THUMB *stretched out at right angles to the hand and pointing towards the* N-END *of the needle. The* FINGERS *point* IN THE DIRECTION *the current flows.*

Question 8. What is an electro-magnet?

Answer. An electro-magnet consists of a coil of wire,

a piece of soft iron to fill the hollow of the coil and a current to pass through the wire.

Fig. 93 shows this, as well as the lines of magnetic action.

Question 9. What are the technical names of the parts of an electro-magnet?

Answer (1) The iron is called the core.

(2) The coil of wire is called a helix.

(3) The helix carrying current (without a core) is called a solenoid.

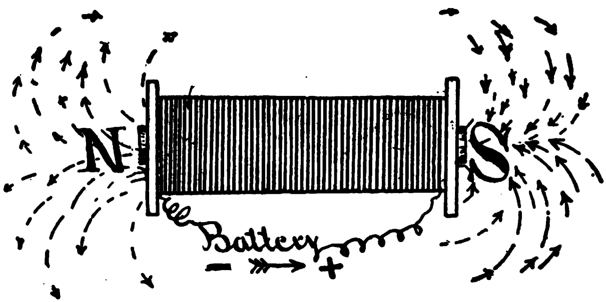


Fig. 93. An Electro-Magnet with its Magnetic Field.

(4) A core placed in a solenoid makes it an electro-magnet.

Remember plugs of brass, fiber or other materials placed in a solenoid are not cores in the technical sense of the word.

(5) The helix or coil is usually not wound on the core but on a spool of brass or bronze. The ends of this spool are called the flanges and show in Fig. 93.

(6) On horse shoe magnets the iron connecting the two cores is called the yoke.

Question 10. Why is the left end an N-pole and the right end a S-pole. (In Fig. 93).

Answer. The polarity of a magnet depends on the direction of the current flow through the helix.

In Figs. 94 and 95 the current enters at the right hand end of the helix, but being wound, one right handed and the other left handed the polarities developed are as shown.

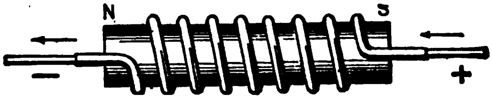


Fig. 94. Electro-Magnet with Right-handed Helix.

Question 11. What rule will give you the polarity of a magnet?

Answer. Hold the magnet so that the current flows through the helix away from you. If the current flows round the core in the direction that the hands of a watch or clock move, the pole you are looking at is an S-

Fig. 95. Electro-Magnet with Left-handed Helix.

pole. If the current went counter-clock wise around the core, the pole is an N-pole.

Question 12. Is there any other rule?

Answer. Yes. It is a rule especially applicable to winding horse shoe magnets so that both legs of the

magnet will not be accidentally made of the same polarity.

Write on the pole piece the letter S or N as the case may be and put arrow heads on the ends of the letters as in Fig. 96. These arrow heads show the direction the current must flow around the core to give the polarity indicated by the letter.

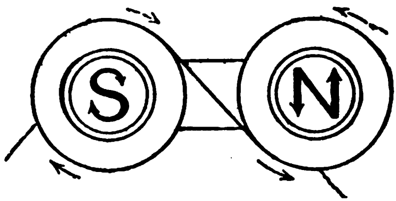


Fig. 96. Rule for Proper Winding of Horse-shoe Magnets.

Question 13. What is the strength of a magnet?

Answer. The term "the strength of a magnet" is used very carelessly. Some people mean its lifting power, while engineers and electricians mean the actual quantity of magnetism flowing from a pole piece.* The expression "strength of a magnet" should only be used as engineers or electricians use it.

Question 14. What is the lifting power of a magnet?

Answer. It is the number of pounds the magnet will hold up, when things are arranged as in Figs. 97 and 98.

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*In electro-magnets when we say pole we generally mean the end of the core. Usually we say pole piece, meaning the surface at the end of the core, or the piece of iron which is screwed, bolted or even cast on the core to make the actual pole larger than the core.

There are some very curious things about lifting power. It depends upon the shape of the magnet, and the actual quantity of magnetism. A horse shoe magnet will lift three or four times as much as a bar magnet of equal strength. A long bar magnet will lift more than a short one; the actual quantity of magnetism being the same.

Fig. 97. Horse-shoe Magnet Arranged for Test of Lifting Power.

Fig. 98. Testing Lifting Power of a Solenoid.

A magnet with round or pointed pole pieces will lift more than the same magnet with flat or broadened pole pieces. The same magnet may have its lifting power changed by unscrewing its pole pieces and screwing on a flatter set.

It is an excellent joke to wind a horse shoe magnet with one pole piece flat and the other rounded. If one will hold 5 pounds the rounded one will hold 6 pounds.

A magnet having its armature loaded almost to the pulling off point, may have its load increased slightly the next day. This gradual increase of the load may be attempted every day until finally the armature will be torn off.

It will be found that the last day the magnet was holding up a load that it could not have held had it been applied all at once. This may be easily proved by trying a load a little less than that which tore the armature away. The magnet will not be able to hold it.

Doubling the strength of the same magnet more than doubles its lifting power, but a magnet will not pull twice as strongly if you move up twice as close to it.

A test made with the armature in contact with the poles of the magnet with increases in the magnets' strength gives practically the following results for lifting power.

Do not forget that doubling the current in an electro magnets coil does not double the strength. This will be fully explained later.

Test 1.

Relative strength of Magnet.	Relative lifting power.
1	1
2	4
3	9
4	16
5	25
6	36
7	49
8	64
9	81
10	100

Test 2.

A test made with a horse shoe magnet to determine its lifting power at different distances from its poles shows the following results:

Distance away from poles.	Lifting power.
0	82.0
1	35.0
2	25.0
3	20.0
4	15.1
5	12.1
6	11.3
7	9.3
8	7.4
9	6.5
10	5.5

LAW OF DIRECT AND INVERSE SQUARES.

The results of Test 1 are not the actual figures in the test. They have been increased or diminished a little in order to illustrate what is called the *Law of Direct Squares.*

By looking at the table of results you will notice that the lifting power is always the strength of the magnet multiplied by itself. For instance when the magnet was 5 times as strong as before it lifted 5x5 or 25 times as much.

When the magnet strength was increased from 1 to 2 the lifting power was increased from 1 to 4. Doubling the strength quadrupled (2x2) the lifting power.

With a magnet 5 units strength, doubling its strength, quadrupled its lifting power; increased it from 25 to 100.

We call a number multiplied by itself a square. The number which is multiplied we call the *square root.*

To find the lifting power of a magnet square its strength.

Having found this rule we could go farther than the results of the test and predict that if the magnet had been increased in strength to 12 times the original value, the lifting power would be 12x12 or 144.

The greater the strength of the magnet the greater the lifting power. This is called a direct relation.

The complete rule as stated in text books is:

The lifting power of a magnet varies directly as the square of its strength.

Varies means changes.

Directly means they both increase.

Square means multiply strength by itself.

The results in Test 2 do not seem to follow any rule. Even if the figures were changed a little as in Test 1 they could not be made so as to get a rule from them.

It is stated in nearly all text books that the lifting power of a magnet decreases according to the square of the distance from the magnet. They state the rule thus:

The attraction of a magnet varies inversely as the square of the distance.

This rule is true with very tiny magnets at small distances and in a space absolutely neutral, free from any magnetism, even the earth's effect.

Under the circumstances of ordinary life this rule is worthless.

What the test shows is this:—As you recede from a magnet the lifting power decreases at first rapidly and then more slowly.

The word *inversely* in the rule means the greater the distance the less the lifting power.

The inverse square of a number is found by squaring the number and placing it in the denominator of a fraction whose numerator is 1.

Example:

Numbers	1	2	3	4	5	6	etc.
Direct Squares	1	4	9	16	25	36	etc.
Inverse Squares	1	$\frac{1}{4}$	$\frac{1}{9}$	$\frac{1}{16}$	$\frac{1}{25}$	$\frac{1}{36}$	etc.

The peculiar thing about 1 is that 1x1 is still 1 and that the fraction 1-1 is still 1.

The importance of these laws of direct and inverse squares is greatly magnified. At the best magnets do not follow the first rule closely, and they do not follow second rule at all.

LESSON 13.

ELECTRO-MAGNETISM—CONTINUED.

Question 1. What is the "strength" of a magnet, speaking in a correct manner?

Answer. The actual quantity of magnetism flowing through one square inch of the surface of the pole piece.

Question 2. How is this quantity of magnetism measured?

Answer. Scientists have selected for a unit of magnetism a quantity they call a "line."

Their tests for the presence of "lines" and the determination of how many "lines" there are in a magnet, need not worry us, as the engineer's job is usually to produce "lines."

Take a stick of wood one inch square, wrap around it a piece of wire making one complete turn and no more. Pass a current of one ampere through this turn of wire and you will produce a flux of a little over 3 lines.

Question 3. What does Flux mean?

Answer. The term flux is used to speak about the total quantity of magnetism. For example, a designer will say that the flux from a magnet is 3½ million lines.

Question 4. What is meant by Density?

Answer. By density we mean the flux per square inch. A designer may say that both these magnets have a flux of 2 million lines; but this one having a density of 10 thousand lines has a smaller core than the other, the density of which is 5 thousand lines.

To get the flux of a magnet multiply the density by the area of the pole piece in square inches.

Knowing the flux we find the density of any part by dividing the flux by the area of that part in square inches.

Question 5. What is meant by Intensity of magnetization?

Answer. It is an out of date term among engineers. A man using the expression probably means density.

Question 6. What is meant by Magnetizing Force?

Answer. Magnetizing force or Magneto-motive force, means the force that is causing magnetism to flow out of the pole piece. In other words magnetizing force is the cause of flux.

Question 7. How is magnetizing force measured?

Answer. Since one turn of wire carrying one ampere current causes a definite flux, we use this as the unit to measure magnetizing force. It is called the Ampere turn.

Experiment shows that half a turn of wire and two amperes cause the same flux as three turns and one third of an ampere. In fact, an ampere turn is any combination of turns and currents arranged so that the number of turns multiplied by the current in amperes gives a product of one.

Question 8. Upon what does the flux from a magnet depend?

Answer. (1) Material of core.
(2) Length of core.
(3) Number of turns of wire in coil.
(4) Current in coil.
(5) Shape of magnet.

Question 9. Why does the material of the core affect the magnet?

Answer. To answer this clearly let us go back a little. A solenoid such as shown in Fig. 99 has a certain flux whose density is calculated by the following rule.

The density is equal to the number of Ampere-turns multiplied by 0.313 and divided by the length of the solenoid in inches.

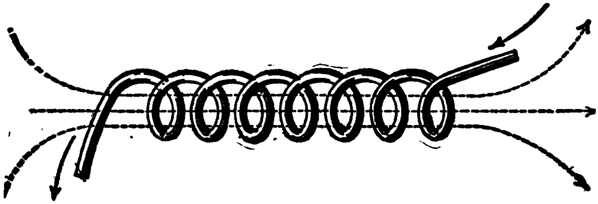

Fig. 99. Flux in a Solenoid.

If the solenoid is very short the density at the ends may be much less than in the middle.

Let us assume that we have a solenoid with a central space one square inch in area and of such a number of turns and carrying such a current that it has 3133 A. T. (ampere-turns) to each inch of its length.

Since one A. T. gives a flux of about 3 lines per square inch (see A 2), these 3133 A. T. will give a flux of 10,000 lines.

Let us take a solenoid like Fig. 99 and slip a wrought iron core into it making a magnet as in Fig. 100. Have the area of the bars' end one square inch (a bar 1⅛ inches in diameter has a cross section of practically 1 square inch).

Let the magnet have such a helix and carry such a current that there are 2.2 A. T. per inch of its length.

The flux of this magnet will be 10,000 lines.

This experiment can be completed by making a magnet of $1\frac{1}{8}$ inch diameter cast iron rod with 18.5 A. T. per inch, and the flux will again be 10,000 lines.

It is quite evident then that the core has great influence on the strength of the magnet.

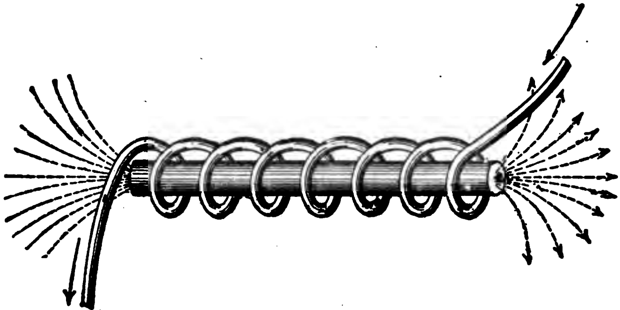

Fig. 100. Flux in a Magnet: i. e., a Solenoid with Iron Core.

The explanation is that wrought iron has far greater permeability than air and so 2.2 A. T. per inch can induce in the wrought iron as much flux as 3133 A. T. per inch could induce in air.

The permeability of cast iron being less than wrought iron it takes 18.5 A. T. to do the work that 2.2 A. T. did before.

Question 10. How does the length of the core affect the flux?

Answer. In this way 500 A. T. wrapped on an $1\frac{1}{8}$ inch round iron* bar one inch long would give a flux of

*When we speak of iron we mean in general wrought iron or Bessemer steel. When we mean cast iron we generally say so. Bessemer steel is cast iron with the extra carbon burnt out. It is nearer to wrought iron than any other metal.

115,000 lines; while if the bar was 10 inches long there would only be a flux of 90,000 lines.

Question 11. Why does not the same number of A. T. give the same flux?

Answer. Because the iron although a good conductor of magnetism, offers some opposition to the flux. So if 500 A. T. can induce in a core one inch long, a flux of 11,500 lines, in a longer core it is to be expected that the flux will be less.

The magnetizing force of 500 A. T. can only do a certain amount of work and the longer the path the flux must be forced through, the less flux there will be.

To get the same flux through different lengths of circuit the A. T. per inch of circuit must be the same.

Question 12. Well then, if 500 A. T. give a flux of 115,000 lines through 1 inch of iron, why did they not give 11,500 or 1/10 of 115,000 through the 10 inch piece? Instead of that you say 500 A. T. on a 10 inch piece give a flux of 90,000 lines.

Answer. The reason is that while iron is more permeable than air the exact degree of permeability depends on the density.

500 A. T. on a 1 inch piece is 500 A. T. per inch.

500 A. T. on a 10 inch piece is 50 A. T. per inch.

Five hundred A. T. per inch can only create a flux of 11,500 per square inch because the density is so high that the iron offers a great deal of opposition to the flux. while 50 A. T. per inch, not being strong enough to create a great flux, finds the iron offering less opposition and is able to create a flux per square inch of 90,000, or nearly eight times what you would expect.

Question 13. Why does iron offer different opposition at different degrees of magnetization?

Answer. Why iron should need greater and greater increases of magnetic force to produce the same increases of density (flux per square inch) we do not know. It does not even act in any regular manner.

It is easy to show that this does occur, and perhaps we can understand the peculiar action a little from the following experiment:

Procure a thick short elastic band and a bunch of butcher's wooden skewers.

Place a dozen skewers inside the band points down. No effort is required; they practically fall in. Place another dozen in. Perhaps a gentle pressure is necessary as you begin to feel the pressure of the band.

The next dozen must be pushed in. The following dozen you have to push in one at a time. At last you will have to drive the skewers in, one at a time, with a block of wood or a light hammer.

Evidently the ease with which the skewers can be placed inside the band depends on the number of skewers per square inch you are trying to get in. As the density increases the difficulty of insertion increases.

The iron acts in the same manner. The more flux in a core the greater a magnetizing force is necessary to place additional lines in it.

Question 14. Do all magnetic materials act in this way?

Answer. Every magnetic material acts in this way in its own peculiar fashion.

Question 15. How do the non-magnetic materials such as brass, air, fibre, etc., act?

Answer. Non-magnetic materials act in an ordinary manner. Twice the magnetizing force produces twice the density.

Question 16. What statement can be made about permeability of materials?

Answer. (1) The materials which are in common use are here arranged according to their permeability at a density of 10,000 lines. The first has the greatest permeability.

(a) Annealed wrought iron. } practically equal.
(b) Soft steel castings. }

(c) Cast iron with a little aluminum.

(d) Ordinary grey cast iron.

(e) Air, fibre, brass, zinc, copper. (All practically equal and very low.)

(2) At first the magnetic materials (mentioned in a, b, c, d) give more than twice the density for twice the magnetizing force. Then they change and act regularly for a short time. After this they give rapidly decreasing increase of density for equal increases in the magnetizing force, till at last a doubling of the A. T. per inch hardly increases the density. We then say the material is *saturated.*

(3) They keep the same order of degree of permeability but their actual permeabilities change in different manners.

At 10,000 density a steel casting is 5 times as permeable as grey cast iron, while at 60,000 density steel castings have 18 times the permeability of iron castings.

(4) The permeabilities of all non-magnetic materials may be taken the same as air without much error; and their permeabilities at all densities are the same.

Question 17. How can definite information as to the permeability of a metal be obtained?

Answer. A specimen is cut and tested in a laboratory. For all ordinary use the average results as published in

AMPERE TURNS REQUIRED PER INCH LENGTH TO INDUCE THE FOLLOWING DENSITIES:

A T per Inch.

Density.	Soft Iron.	Soft Steel Castings.	Cast Iron.	Air.
5000	1.7	2.	13.	1566
10000	2.2	3.7	18.5	3133
15000	2.7	4.3	24.1	4700
20000	3.5	5.	30.5	6266
25000	4.5	5.8	39.	7833
30000	5.5	6.6	50.	9400
35000	6.5	7.6	65.	10966
40000	7.5	8.8	88.	12532
45000	8.5	10.1	116.	14100
50000	9.6	11.8	160.	15665
55000	11.1	13.9	222.	17233
60000	13.	16.4	295.	18800
65000	15.7	19.3	400.	*
70000	19.6	22.7	570.	
75000	24.7	27.	*	
80000	31.2	34.		
85000	39.7	44.		
90000	50.7	57.		
95000	67.	75.		
100000	91.	100.		
105000	137.	159.		
110000	290.	325.		
115000	500.	550.		
120000	*	*		
125000				

*The figures are not given when the number of A T becomes excessively large or beyond the usual limits of density.

Air gaps are generally worked at a density below 50,000.

A density of over 105,000 is rarely used in iron or soft steel.

To find the A T corresponding to a density not given:—

How many A T per inch are required for soft steel at density of 37,000.

40000	takes	8.8	Subtract
35000	takes	7.6	
5000		1.2	Divide by 5
1000		0.24	Multiply by 2
2000		0.48	Add in
35000		7.6	
37000	takes	8.08	A T per inch.

This scheme is called interpolation and can be applied to any table.

books and magazines can be used. This table is taken from A. E. Wiener's book on dynamo designing.

Question 18. What is Reluctance?

Answer. The name reluctance is given to the total opposition offered by a piece of material to the passage of flux.

Question 19. What is Reluctivity?

Answer. Reluctivity is the reluctance of a piece of material one inch long and one square inch in cross section.

Question 20. Why are the two words necessary?

Answer. Because it is necessary to express the reluctances of magnetic circuits. It is equally necessary to express the reluctances of exactly similar pieces of different materials. To do this we would have to use the expression "reluctance per cubic inch" unless we use "reluctivity."

Question 21. Why do we not hear the word reluctivity used more frequently?

Answer. Because we usually are thinking about the conductivity per cubic inch instead of the opposition per cubic inch.

The conductivity of a piece of material one inch long and one square inch in cross section is called its permeability. It is this latter word which we use.

Question 22. What is Permeance?

Answer. The name permeance is given to the total conductivity of a piece of material for flux.

Question 23. What is meant by saying that reluctivity is the reciprocal of permeability?

Answer. When two things are opposite in sense, as reluctivity and permeability, one being the opposition

the other the conductivity, of the same piece of metal, we call them reciprocals of each other.

If the permeability of iron is 200, its reluctivity is 1/200, for the greater the permeability the less the reluctance.

Question 24. What is Retentivity?

Answer. A piece of iron becomes a magnet temporarily under the influence of ampere turns but loses nearly all its magnetism when the current is cut off from the helix.

What remains is called Residual magnetism. The residual magnetism per cubic inch is called the retentivity of the iron.

Iron or soft steel has very little retaining power; hard steel has great retentivity.

Question 25. Is residual magnetism a good or bad thing?

Answer. It depends. In dynamo armatures we would rather not have it; in the yokes of the magnets we are very glad of it.

In telegraph relays we try to reduce it as much as possible.

A peculiar thing about residual magnetism is that a piece of soft iron which has been under the influence of a magnet only a thousandth of an inch away will show less residual magnetism than if it had been in actual contact.

Telegraphers take advantage of this and paste tissue paper on the armatures of relays and sounders so that they may come very close to the magnetic cores and yet never come accidentally in actual contact.

Question 26. The word saturated was used in A 16. What does supersaturated mean?

Answer. It is possible to magnetize a piece of steel so strongly that when tested instantly after magnetizing, it shows a strength in excess of what it will show four or five hours after.

This second strength is its permanent strength. It can be magnetized permanently no stronger than this second strength, so this is called saturation.

Question 27. What is a magnetic circuit?

Answer. From experiments which were first made with permanent magnets it seemed as if the flux of a magnet simply came out of each end. Later when the result of breaking a magnet was discovered, it was recognized that the flux must also pass through the middle of the bar.

What became of the flux after it left the poles was for a long time unknown. Experiments like Fig. 80 made electricians suspect that the flux which left one pole went around through the air and entered the other pole.

In fact people soon began to believe that magnetism flows around a circuit just as electricity does.

In the case of the electric circuit it is all copper wire, while the magnetic circuit is usually composed of iron and air.

Question 28. Can you give other reasons for believing that flux flows around a circuit?

Answer. Yes. Make an electro-magnet of a ring of iron and a coil wound on as in Fig. 101 A. It will show no polarity at all, and be only slightly magnetic. Saw out a piece of the metal and the ring will develop polarity at N. and S. as shown in B.

This shows that the magnetism flowed around the ring and also across the air gap when one was made.

Question 29. Why was there no polarity in Fig. 101 A?

Answer. Because the iron being a good conductor the flux passes through it and practically none is in the air where the testing needle was put.

But if a hole should be bored in the ring and the compass dropped into it, then the polarity would show, because flux would pass through the compass.

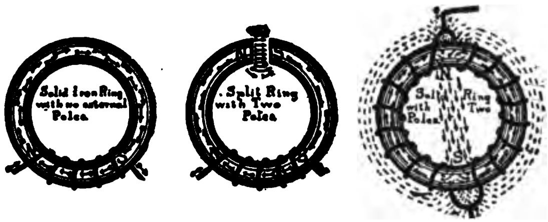

Fig. 101. Magnetic Polarity of an Iron Ring.

Question 30. Why did Fig. 101 B show polarity?

Answer. Because the air gap being a poor conductor, the flux spread out as indicated and affected a compass needle brought near it.

Question 31. Why should Fig. 101 C develop poles at opposite sides of the ring and why should it show so much magnetism in the air around it.

Answer. The left hand part of the winding produces a N-pole at top of ring. The right hand portion does the same thing. These North polarities oppose each other and force the flux out of the iron on both sides.

Part of the flux passes directly across inside of ring to the S-pole and the rest curves around the outside of the ring through the air.

Question 32. What are closed and open magnetic circuits.

Answer. A circuit composed entirely of iron or magnetic metals is called a closed circuit, while a circuit with an air gap in it is called an open circuit. Even if the air gap is filled with brass, fibre, etc., the circuit is still an open one.

Figs. 101 B and C show open circuits. In C the iron is a continuous ring but there are two magnetic circuits each composed of a half ring of iron and an air space across which the flux passes.

The results shown in Figs. 83, 84, 85 and 86 can be explained by magnetic flux and magnetic circuits, remembering that the permeability of even hard steel is many times higher than air, which means that its reluctivity is many times less.

Suppose that in Fig. 83 only the first magnet with the nails hanging to its N-pole is present. The flux from the N-pole passes around the magnet to its S-pole. The superior permeability of the iron nails makes most of the flux pass to the S-pole through them. This makes them temporary magnets and they stick together.

Now suppose the top magnet to be slid over the under one. The permeance of the magnetic circuit composed of the two magnets lying side by side is much greater than that of the circuit composed of one magnet, the nails and all the air from the end of the last to the S-pole of the first magnet.

Naturally the greater part of the flux goes through the new path and the part of the flux through the nails is too small to strongly magnetize them. Their magnetism being reduced they cease to adhere and drop off.

The second magnet acts as a shunt circuit for the flux

and being of great permeance robs the nails of the flux that magnetized them.

In Fig. 84, when only the first magnet was there, we had rather a poor magnetic circuit—a piece of steel, the nails and a long air gap from last nail to S-pole of magnet.

When the second magnet is put in position, the permeance of the circuit is improved because the air gap has been shortened. (Measure it and see.) Furthermore, in a circuit of greater permeance we have double the magnetizing force.

In Fig. 85, the adding of the second magnet increases the permeance and the magnetizing force. In Fig. 84 we reduced the air gap, while in Fig. 85 the air gap is left the same; hence the increase in inductive effect in Fig. 84 is greater than in Fig. 85.

In Fig. 86 the addition of the second magnet gives a result something like that shown in Fig. 101 C. The flux from the two N-poles which passes between the magnets is very weak and does not magnetize the nails sufficiently. The greater part of the flux goes back outside of the magnets.

LESSON 14.

LAW OF MAGNETIC CIRCUITS.

It is natural to suppose that there is some direct connection between the value of the magnetizing force and the flux induced. Also between the reluctance of the circuit and the flux induced.

These three things: the magnetizing force, reluctance, and flux are connected in the following way:

$$\text{Flux} = \frac{\text{Magnetizing force.}}{\text{Reluctance.}}$$

This formula while not of much practical use is of the highest importance theoretically. By that I mean: It is only by learning this formula by heart and understanding what it means that we can get a clear idea of how the flux in a circuit changes with the changes of magnetizing force, and how the changes of reluctance affect the flux.

Let us once more be sure that we know what the terms used mean.

Flux is the total amount of magnetism in the core, expressed as so many lines.

Magnetizing Force or Magneto-motive Force is the total pressure trying to send flux through the circuit. It is expressed by ampere turns multiplied by 1.25.

Reluctance is the total opposition offered by the circuit to the passage of flux.

The greater the magnetizing force the more flux; the greater the reluctance the less flux.

Let us see how this formula could be applied to a problem in a designer's office.

He would generally know what flux he wanted and he would know what kind of a circuit he intended to use, so he would want to find out how many ampere turns must be wound on the spools.

He must find the reluctance of the circuit. Then knowing two things he can twist the formula into this shape:

$$\text{Magnetizing force} = \text{Flux} \times \text{Reluctance.*}$$

$$\text{Ampere turns} = \frac{\text{Flux} \times \text{Reluctance}}{1.25}$$

The reluctance of a circuit is equal to the reluctivity of the material multiplied by the length and divided by the cross section of the circuit.

This must be so because the reluctivity is the opposition per cubic inch. The longer the circuit the greater the reluctance and the greater the area of the cross section the less the reluctance.

In the first case the flux has further to travel and in the second case has more room to travel in.

Calling *L* length of circuit in inches and *a* its area, the formula becomes:

$$\text{Ampere turns} = \frac{\text{Flux} \times \text{reluctivity} \times \text{L}}{1.25 \times \text{a}}$$

This designer will not find any tables of reluctivity in books, but he can find tables or curves† of permeability.

Reluctivity is the reciprocal of permeability.

*The way these formulas are changed will be more fully explained at the end of the lesson.

†Curves and their use will be explained at the end of this lesson.

If a man can do a job in 6 days he can do 1/6 of it in one day.

The part he can do in one day is the reciprocal of the number of days needed to do the whole job.

$$\text{Reluctivity} = \frac{1}{\text{Permeability}}$$

The formula he is using now becomes

$$\text{Ampere turns} = \frac{\text{Flux}}{1.25} \times \frac{\text{L}}{\text{a} \times \text{permeability}}$$

To make this formula more compact letters are used for the words.

Different books use different letters, some even using German or Greek letters for the names.

We will use A T for ampere turns. X (the last letter) for flux; and p (the first letter) for permeability.

The formula now looks like this:

$$\text{A T} = \frac{\text{X} \times \text{L}}{1.25 \times \text{a} \times \text{p}}$$

This is a short way of saying:

The ampere turns required to excite a magnet so as to produce a flux X are found in this way.

(1) Find the product of the flux and the length of the circuit.

(2) Find the continued product of 1.25, the area of the cross section of the circuit, and the permeability of the material.

(3) Divide the first product by the continued product.

By fussing with this formula the designer has obtained a knowledge of magnetism that can be obtained in no other way, but about this point he is apt to be disgusted

with the formula. He now on looking up the permeability tables or curves finds that he must calculate the density i. e. flux divided by area before he can find the permeability he wants; for the permeability changes with the change in density.

After doing this he can replace each letter in the formula by the proper number and calculate the ampere turns.

This formula may be changed to appear as:

$$X = \frac{1.25 \times a \times p \times A\,T}{L}$$

This form is useless as a quick and accurate means of calculation for you must know the answer before you start. This is evident because *p* cannot be obtained until density is known and density is unknown until the total flux is determined.

The way to use this formula is to guess at an answer, use a value of *p* accordingly and if the answer comes out too far away from the guess, correct the value of *p* and solve again.

These formulas are not used in designing.

The designer proceeds as follows:

Suppose he has a magnetic circuit of type shown in Fig. 102. Y is the yoke which measures 12 inches between centers of holes into which the poles P. are set. The path of the flux through the poles is 14 inches long in each.

The part marked *a* is of sheet iron (annealed wrought iron sheets). The wires *w* are of copper. Between the armature iron and the pole piece on either side is an air gap of half an inch.

The magnetic circuit is through $2 \times 14 = 28$ plus $12 = 40$ inches of steel casting. Through 10 inches of sheet iron, and one inch of air gap.

The pole pieces are, roughly, square 6x6 inches. The parts of P inside the coils or bobbins B are circular, 5 inches in diameter. The yoke is a slab 5x12 inches. Armature is 7 inches long and 7 inches wide.

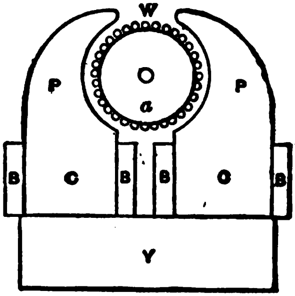

Fig. 102. The Magnetic Circuit of a Small Motor.

The flux required is 1,800,000 lines. How many ampere turns must the bobbins B contain?

From the laboratory connected with the factory he has obtained a table as is given in Lesson 13. Ampere Turns Required per Inch for Different Densities.

He figures the densities:

Yoke: $12\text{x}5 = 60$ sq. in.
$1{,}800{,}000 \div 60 = 30{,}000$ lines.
Poles: 5 inch circles $= 19.6$ sq. in.
$1{,}800{,}000 \div 20 = 90{,}000$ lines.
Air gaps: $6\text{x}6 = 36$ sq. in.
$1{,}800{,}000 \div 36 = 50{,}000$ lines.
Armature: $7\text{x}7 = 49$ sq. in.
Say 50 sq. in.
$1{,}800{,}000 \div 50 = 36{,}000$ lines.

Looking at the table he finds steel castings at density of 30,000 lines take 6.6 A T per inch; at 90,000 lines they require 57 A T per inch.

Air at a density of 50,000 requires 15,665 A T per inch; while sheet iron at 36,000 density needs 6.7 A T per inch.

Referring back to the lengths of the circuits and tabulating the data he has:

Material.	Density.	A T per inch.	Length.	Total A T required.
Steel.	30,000	6.6	12	792
Steel.	90,000	57	28	1,596
Air.	50,000	15,665	1	15,665
Iron.	36,000	6.7	10	67
Grand total				18,120

Since there are two coils there will be 9,060 A T on each leg of the magnetic circuit.

With a current of 1½ amperes 6,040 turns of wire will be required.

In a similar manner when a designer wishes to know the flux that a magnet will produce, he measures its area and length. He then figures from the number of turns in the coil and the current he intends it to carry what the ampere turns are. Then he figures the ampere turns per inch and looking up in the table finds the density induced. Multiplying this by the area gives him the flux.

This latter calculation can only be made when the circuit is of one material and of the same size throughout, but one makes this calculation only once to a thousand calculations of the ampere turns required.

In cases where the circuit is of varying dimensions and materials the ampere turns must be apportioned to each part of the circuit before the figuring is done.

Question 1. Suppose two pieces of Bessemer rod* each a foot long, one 1⅛ inch the other 3¾ inches in diameter, were each to be magnetized to a density of 77,500 lines (per square inch). How many ampere turns would each need?

Answer. Table says 30 A. T. per inch for density of 77,500 for soft steel. One foot is twelve inches. $12 \times 30 = 360$ A. T.

Question 2. But both will not require the same number of ampere turns? One is 1 sq. in. in area, the other is 11 sq. in.

Answer. They both need the same magnetizing force because the lengths and densities are the same.

Question 3. But if 360 A. T. are placed in each rod there will be a flux of $1 \times 77{,}500 = 77{,}500$ in one, and $11 \times 77{,}500 = 852{,}500$ in the other. How can this be?

Answer. Because 360 A. T. on a 1 sq. in. rod produces 77,500 lines, but the 3¾ diameter rod having 11 times the area of the smaller rod offers only one-eleventh the reluctance and hence the flux is eleven times as great or 852,500 lines.

But as flux is 11 times as great and area 11 times larger the density is the same.

Question 4. Can you explain this in a different way?

Answer. Suppose 36 turns of wire are made in one end of a long piece; making the turns around a piece of 1⅛-inch round wood, and a 10 ampere current is sent

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* Bessemer rod is rolled from the same material that steel castings are poured. They are almost like iron. When purchased they have a plating of copper on them to prevent rusting.

through the whole wire. Suppose the turns are pulled apart until they are evenly spaced and the first and last turns 12 inches apart. This solenoid has now $10 \times 36 \div 12 = 30$ A. T. per inch. This will produce a density of 98 lines, say 100, in the air inside the solenoid.

Suppose now the whole wire is used to make the 36 turns. Keep the spacing the same but let the turns be nearly 10 inches across, from side to side. There will be an area of 78.5 sq. in. now under the influence of the solenoid.

Each square inch is just as powerfully excited as before, since there are 30 A. T. per inch surrounding it. Each of the square inches in the whole 78.5 will have 100 lines induced in it.

Question 5. Can you express this result as a rule?

Answer. No matter what the size of a core the flux per square inch (density) depends on the number of ampere turns on each inch of its length.

An expression

$$\text{Flux} = \frac{\text{Magnetizing force}}{\text{Reluctance}} \qquad (1)$$

when written

$$X = \frac{A\,T \times 1.25}{Z} \qquad (2)$$

is called an algebraic formula.

These formulas are capable of assuming different forms, but all these forms are brought about in a regular manner.

Rules may be given to teach one how to make the changes but the principle underlying the rule should be understood.

To place a term such as Z on the other side of the equal sign, remember that it must be moved either up or down. If in the denominator on one side it must move to the numerator on the other side. If in the numerator on one side it must be placed in the denominator on the other. Whole numbers are to be considered as in a numerator.

In (2) let us place Z on the left hand side of the equal sign.

$$Z \times X = A\,T \times 1.25. \qquad (3)$$

The reason for this rule is: Formula (2) must be considered as an *equation*. The left side is equal to the right side. Nothing must be done which will disturb this equality.

If we multiply both sides of (2) by Z, the equality will not be affected, and the equation will look like

$$Z \times X = \frac{Z \times A\,T \times 1.25}{Z} \qquad (4)$$

But the two Z's on the right and side cancel, and we have

$$Z \times X = A\,T \times 1.25. \qquad (3)$$

Suppose that in (2) we wished to change the formula so that the term A T would stand alone.

Z comes to the left numerator; 1.25 comes to the right denominator, and we have

$$\frac{Z \times X}{1.25} = A\,T \qquad (5)$$

Since these things are equal it makes no difference which is written first, so we write

$$A\,T = \frac{Z \times X}{1.25} \qquad (6)$$

To substitute for Z any other letter or expression, we must first be sure that the thing we wish to substitute is exactly equal to Z.

From the Lesson we know

$$Z = \frac{1}{a \times p} \qquad (7)$$

Substitute in (6) for Z its value as given in (7) by writing in the space occupied by Z the other expression:

$$A\,T = \frac{\frac{1}{a \times p} \times X}{1.25} \qquad (8)$$

The right hand side is now a complex fraction which must be simplified.

Do so in this way: Copy the numerator of the complex fraction down separately.

$$\frac{1}{a \times p} \times X \tag{9}$$

Multiply the fraction by the whole number X in the ordinary way of arithmetic:

$$\frac{1 \times X}{a \times p} \tag{10}$$

Go back to the complex fraction and copy its denominator changing it to a fraction.

$$\frac{1.25}{1} \tag{11}$$

Now draw a heavy line; place (10) above it and (11) below it.

$$\left\{\frac{\dfrac{1 \times X}{a \times p}}{\dfrac{1.25}{1}}\right\} \tag{12}$$

Multiply the extreme top and bottom of (12) for a numerator, and multiply together the middle parts for a denominator, as shown by the brackets. This gives

$$\frac{1 \times X}{a \times p \times 1.25} \tag{13}$$

which we can put back in (8) and get

$$AT = \frac{1 \times X}{a \times p \times 1.25} \tag{14}$$

Rearranging the letters we get

$$AT = \frac{X \times 1}{1.25 \times a \times p} \tag{15}$$

as we did in the Lesson.

CURVES.

The use of curves in engineering work was started with an idea of showing results quickly and making them easily understood.

Suppose you were trying to impress on a man's mind the fact that the traffic on suburban trains varied in a regular manner every morning and evening, and that the through trains were evenly loaded all day. Also that the weight of the passengers in the through trains averaged 5% of the weight of the train, while the weight of suburban passengers varied from 2% to 20% of the train's weight, according to the time of day.

Hand him the following table and while the information is there it will take him some time to get it into his head. Ask him suddenly: "At what times are the suburban and through trains equally loaded with passengers?"

See how long before he finds the information which will enable him to answer.

Table of the Percentage of Passenger Weight to Light Train Weight, Grand Central Station to Mott Haven Junction, New York.

SUBURBAN TRAINS.

Time.	Percentage.	Time.	Percentage.
Midnight	2.	6	12.
1	2.25	7	18.
2	2.75	8	20.
3	3.	9	18.5
4	3.5	10	14.5
5	5.	11	9.

Time.	Percentage.	Time.	Percentage.
Noon	8.25	6	19.
1	8.5	7	19.25
2	8.75	8	16.
3	9.5	9	10.5
4	11.	10	6.5
5	16.	11	4.25
Midnight	2.		

THROUGH TRAINS.

Five per cent at all hours.

Now hand him the following curve (Fig. 103):

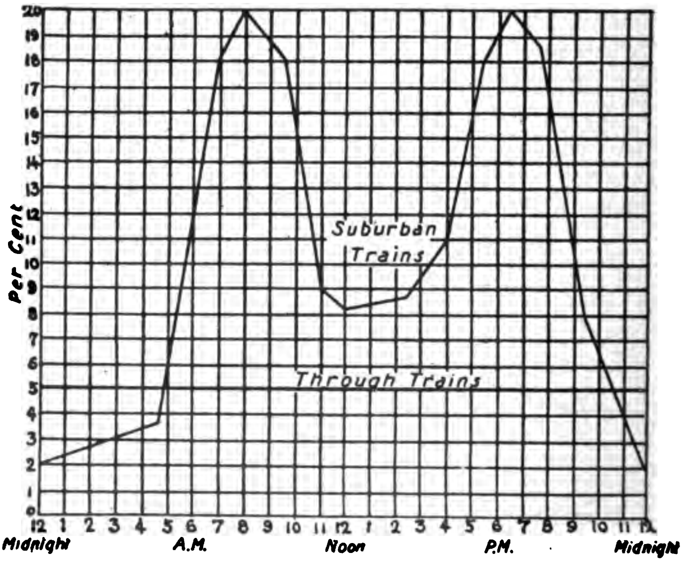

Fig. 103. Percentage of Passenger Weight to Total Weight of Train.

How quickly he grasps the way in which the traffic varies. He notices much more quickly than he would by use of the table that from 5 to 8 in the morning there is an abrupt rise in traffic, while from 6:30 to 11 in the evening there is an equal decline in traffic at a much slower rate. He notices the great changes in train loads between 5 and 7 in the morning and the slight change between 2 and 4 in the afternoon.

Ask him again the question, and see how quickly it is answered.

A curve is certainly a great thing for imparting information.

The curve is drawn from the table in the following way: Procure a piece of paper printed with lines running across at right angles in both directions and at some convenient distance apart, say 1/10 of an inch, or for finer work, 1 millimeter.* This is called cross-section paper.

Determine which of the set of two numbers you are most anxious to have show up strikingly, and number each line up along the left edge accordingly.

Each space can be 1%, but if the percentages run up very high, you might have to call each space 5%.

Number the lines along the bottom of the sheet according to hours. Let one space represent 15 minutes or one-quarter of an hour, or if there is not room for this, let each space count one hour. When the lines are properly numbered, lay out the curve.

Place your pencil on the first vertical line (marked midnight). Run pencil up along this line until you reach

---

* A millimeter is 1/10 of a centimeter, i. e. about 0.04 of an inch.

the horizontal line marked 2%. Make a dot where these two lines meet.

On the next line, marked 1 a. m., run the pencil up till opposite a point one quarter the way up between the 2 and 3% lines. This represents 2.25. Make a dot here.

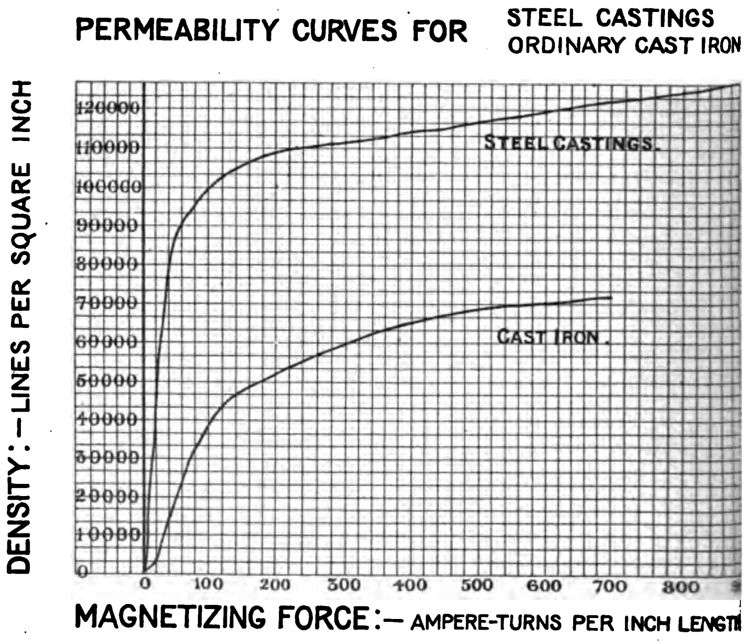

Fig. 104. Permeability Curves.

With the figures from the table in this way make a dot at the point where the vertical time line cuts the horizontal per cent line.

There will be one dot for every set of figures in the table. When all dots are placed, draw a line through them and you have the desired curve.

Figure 104 contains two curves drawn from data obtained from the table of ampere turns per inch at different densities.

Certain information can be more easily gained and is shown in a more impressive manner by these curves than by the table.

Notice that as you steadily increase the A. T. per inch on a steel casting at first the result is a great increase in flux, and the density rapidly increases, but after a while the density increases very slowly.

With cast iron this same statement is true, but the effect is not so marked. At first you get a rapid increase in density and later a slower increase.

The first and last parts of the steel curves are practically straight lines. Designers often speak of the "straight line portion of the curve." The part between these two is called the "knee" of the curve.

The cast iron curve has no definite straight line portions and the knee is so large that it is difficult to exactly locate it.

LESSON 15.

PRIMARY BATTERIES.

There are many places where we need a small amount of electrical power, so little that running a line to the point would not pay. In such cases we uses batteries.

A storage cell needs more attention than a primary cell, so many automatic signals, call bells, and such are operated by primary cells.

There is a deal of truth in the statement, "There is electricity in everything." The hard job is to get it out.

Suppose you throw a dozen shovelfuls of fine damp coal into the firebox, and forget to close the door. The result you get is not the fault of the coal. It was full of B. T. U.'s[1] and you gave them a chance to get out, but not in the proper manner, and they failed to do the work of making steam.

What a difference there is if this same kind of coal in larger pieces is fired two shovelfuls at a time with just the right quantity of air.

So it is with electricity; we must treat our materials in exactly the correct manner if we expect a production of current worth the money expended.

If one pound of zinc be placed in dilute sulphuric acid[2]

1. B. T. U. is an abbreviation for a British Thermal Unit, being the amount of heat required to raise one pound of water from 39 to 40 degrees Fahrenheit (ordinary thermometer). One pound of good coal contains 1,200 B. T. U.

2. Buy *oil of vitriol* and dilute by pouring the acid slowly into 20 times as much water, stirring with a piece of glass. An earthen ware pot is the safest thing to mix in as the great heat generated will not crack it.

it will dissolve and give out 1,026 B. T. U., but no electricity. You will notice that there are bubbles of hydrogen gas coming up from the zinc and a thermometer would show the increase in temperature. A certain part of the energy liberated might have been obtained as electricity if the zinc were treated in the following way:

Placing the zinc and a piece of copper in a jar of dilute sulphuric acid, not allowing them to touch below the liquid, allowing them to touch above it, or connect them with a copper or iron wire. Now the thermometer will rise very little, electricity will flow through the wire and the wire exhibit magnetic qualities. We agree to say that the current flows from the copper to the zinc outside of the cell and from the zinc to the copper in the liquid.

We have now started into action the simplest of the primary batteries.

This same experiment made with a strong solution of common salt in water will work as well.

If you attempt to use the current from such a simple cell you will find that it is very quickly apparently exhausted.

To be a commercial success a cell should deliver current more or less continuously until its zinc is all consumed.

In the words "more or less continuously" lies the distinction made between cells. An "all around service" cell is difficult to design, so that we have Open circuit, Semi-closed and Closed circuit types of cells.

The main thing in any cell is to avoid the tendency of the cell to "lay down" while there are yet plenty of chemicals in the cell capable of, under proper circumstances, delivering electricity.

This stoppage of the cell's activity is called Polarization.

Return to the simple cell of copper, zinc and sulphuric acid. If it has been used long enough to "lay down," examine the plates. The copper one is entirely covered with bubbles. These are the cause of the cell's non-action. The cell is polarized. The reason for this name and the cause of the non-action will be best understood by first learning this table:

TABLE OF VOLTAIC CELL MATERIALS.

Direction of current through the wire in external circuit.

Positive	Z	I	L	C	S	C	Negative
	i	r	e	o	i	a	
Plates	n	o	a	p	l	r	Plates
	c	n	d	p	v	b	
				e	e	o	
				r	r	n	

Direction of current through solution in cell.

This table is the result of experiments such as you can perform yourself. In another glass of dilute sulphuric acid place two pieces of zinc and connect them. They dissolve but no electricity is delivered. Try two iron plates with the same result, with perhaps less corrosion of the metal by the acid. Two pieces of lead give no electricity and are hardly affected by the acid, while two sticks of carbon are not even attacked by the acid. With zinc and iron you get a weak and almost useless cell, with current flowing from the iron to the zinc. Zinc and copper we know to be good, but we find that zinc and carbon is better.

This table is evidently arranged so that the further apart the metals stand in it the better a cell they make.

This should set you thinking. A zinc plate and a bubble covered copper plate will not make a cell. Therefore bubbles must make a positive plate.

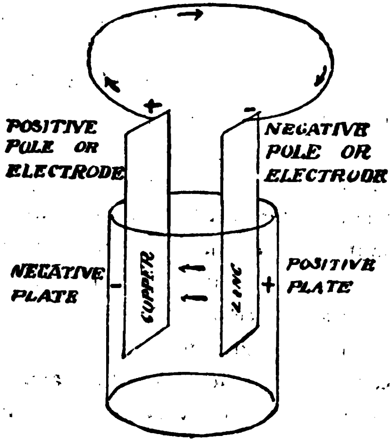

Fig. 105. Names of Parts of Cell.

You must find now what the bubbles are and how they act electrically.

The things in the cells are:

Zinc: that is zinc and impurities.

Copper: that is copper, pure.

Sulphuric Acid: that is sulphur, hydrogen and oxygen.

Water: that is hydrogen and oxygen.

Since the bubbles are of gas they must be either hydrogen or oxygen.

Chemistry books will tell you that oxygen makes a fine negative plate and hydrogen a fine positive plate; just about as good as zinc.

Do so in this way: Copy the numerator of the complex fraction down separately.

$$\frac{\mathrm{I}}{a \times p} \times X \tag{9}$$

Multiply the fraction by the whole number X in the ordinary way of arithmetic:

$$\frac{\mathrm{I} \times X}{a \times p} \tag{10}$$

Go back to the complex fraction and copy its denominator changing it to a fraction.

$$\frac{1.25}{1} \tag{11}$$

Now draw a heavy line; place (10) above it and (11) below it.

$$\left\{\frac{\dfrac{\mathrm{I} \times X}{a \times p}}{\dfrac{1.25}{1}}\right\} \tag{12}$$

Multiply the extreme top and bottom of (12) for a numerator, and multiply together the middle parts for a denominator, as shown by the brackets. This gives

$$\frac{\mathrm{I} \times X}{a \times p \times 1.25} \tag{13}$$

which we can put back in (8) and get

$$A\,T = \frac{\mathrm{I} \times X}{a \times p \times 1.25} \tag{14}$$

Rearranging the letters we get

$$A\,T = \frac{X \times \mathrm{I}}{1.25 \times a \times p} \tag{15}$$

as we did in the Lesson.

The use of curves in engineering work was started with an idea of showing results quickly and making them easily understood.

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Hand him the following table and while the information is there it will take him some time to get it into his head. Ask him suddenly: "At what times are the suburban and through trains equally loaded with passengers?"

See how long before he finds the information which will enable him to answer.

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2	2.75	8	20.
3	3.	9	18.5
4	3.5	10	14.5
5	5.	11	9.

The cell has then two positive plates in it, and has two negative poles. (See Fig. 105.) The cell is polarized.

We have learned so far that a cell must have two different materials immersed in a solution and the more rapidly it attacks one and the less it affects the other the better the cell. For this reason zinc and carbon, being cheap commercial products, are almost universally used in primary cells.

Also a cell to be a commercial success must either not produce hydrogen gas or get rid of it after production.

We will now describe some of the most used cells, classifying them under headings as follows:

Open circuit: A cell designed for intermittent work. Periods of work short, intervals of rest long. Usually designed for small currents. When not in use these cells must be left on open circuit.

Semi-closed: A cell designed for fairly steady work. Periods of work long, intervals of rest short. Often designed to produce heavy currents. When not in use these cells must be left on open circuit.

Closed circuit: A cell designed for continuous work. Periods of work long, intervals of rest very short. Usually designed for very small currents. Almost impossible to design so as to produce much current. When not in use they must be left on closed circuit.

Polarization prevented: Cell so designed that no hydrogen gas is produced by chemical action of cell.

Polarization cured: Cell produces hydrogen, but a chemical placed in the cell turns the hydrogen to water, which is harmless.

Polarization delayed: Cell has very large and absorbent negative plate.

CELLS COMMONLY USED IN RAILROAD WORK.

The Carbon Cylinder Cell. These are sold under the name of Law, Samson, Hercules, etc. It is an open circuit, polarization delayed type. They give a pressure of 1.5 volts and have a resistance of 1 to 2 ohms. Two of them are shown in Fig. 106.

The carbon element is made with as large a surface as possible. Carbon and charcoal have a remarkable power of absorbing gases. A cubic inch of charcoal will condense and absorb 20 to 30 cubic inches of gas.

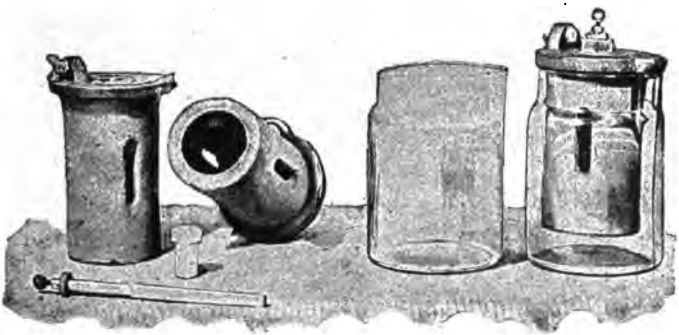


Fig. 106. Carbon Cylinder Cell.

The zinc element is a rod and the fluid a strong solution of sal ammoniac in water. The scientific name of this chemical is ammonium chloride.

The action of the cell dissolves the zinc, forming zinc chloride, which dissolves in the water. A little ammonia and hydrogen gases are set free. The ammonia is dissolved by the water and the hydrogen absorbed by the carbon.

In time the carbon gets soaked full of hydrogen, and to restore the cell it should be taken out and boiled in water for an hour.

These should only be used for call bells in offices or such unimportant work.

Leclanche Cell. This is an open-circuit, polarization cured type. They are made in several forms. Voltage 1.5 and resistance 1 to 4 ohms. Uses sal ammoniac, zinc and carbon.

Fig. 107. Carbon Cylinder Cell with Depolarizer.

The carbon cylinder cell is sometimes modified to the Leclanche type by making the carbon element with a bottom and no opening in the sides. This carbon can or bucket is filled with lumps of black oxide of manganese (manganese dioxide). The zinc is made in a cylindrical form, surrounding the carbon. This cell is shown in Fig. 107.

The hydrogen is absorbed by the carbon but the manganese dioxide, being in contact with the carbon, gives up half of its oxygen to the hydrogen forming water, while it is reduced to manganese monoxide.

This cell is useful for call bell work, operating mag-

nets on interlocking machines, running tell-tales on interlocking boards and such other intermittent light work.

There is an older form of Leclanche cell shown in Fig. 108, where the carbon is placed in a cup of unglazed earthen ware (like a yellow flower pot) called a porous

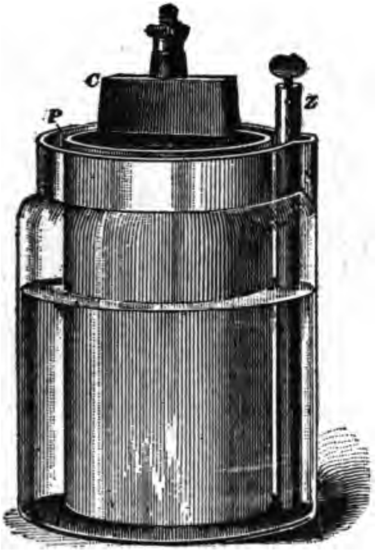


Fig. 108. Ordinary Leclanche Cell.

Fig. 109. Elements of the Gonda-Leclanche Cell.

cup. The manganese is packed around the carbon slab. This form does not give such a large current as the cell in Fig. 107 because its resistance is high, often as much as four or five ohms.

A much used form of the Leclanche cell is the Gonda cell. The elements are shown in Fig. 109.

Here the manganese is powdered, mixed with cheap molasses. then by heat and pressure formed into slabs.

These are attached to the carbon plates by rubber bands. The bother and resistance of the porous cup is avoided.

The usual charge of a Leclanche type cell is a generous quarter pound of sal ammoniac dissolved in sufficient water to fill the jar two-thirds full after elements are in place.

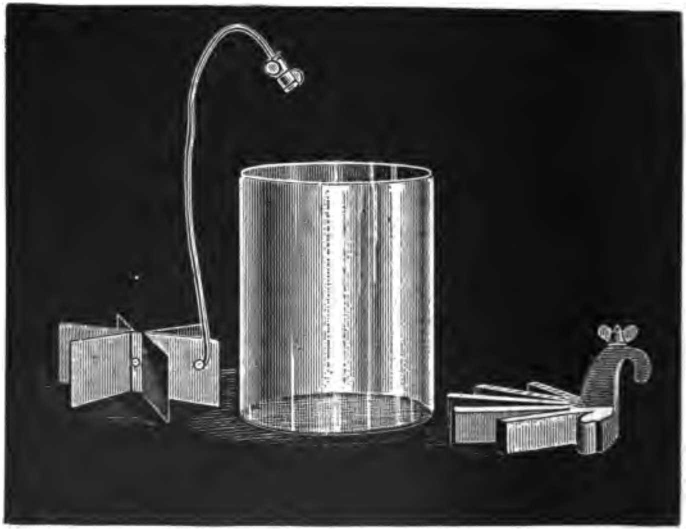


Fig. 110. Elements of Gravity Cell and Jar.

The Gravity Cell. This is a closed circuit cell with polarization prevented. It is very much used for telegraph circuits, operating the electrical devices in the lock and block signals, the motors in automatic signals and generally around interlocking plants. Its pressure is 1 volt and its current capacity rather low for its resistance is 3 or 4 ohms.

This cell is made in many forms called Bluestone cell, crow-foot battery, Lockwood cell, etc.

The parts of a gravity cell are shown in Fig. 110, and the assembled cell in Fig. 111.

Fig. 111. Gravity Cell Ready for Use.

The glass jars should be about 7 inches high and 6 inches in diameter. The zinc is cast in a shape so as to be easily suspended from the edge of the jar. The form shown is called a crow-foot zinc. It weighs about 3 pounds.

The copper element shown on left of Fig. 110 is made of three sheets riveted together at center and then spread out as shown. The rubber covered wire must be attached to the copper element by riveting. If soldered the joint would be eaten away by electrical action.

To set up a cell of ordinary size which holds about 0.8 gallons of liquid make two solutions, one of copper, the other of zinc.

Zinc solution: Pint and a half of pure soft water and 10 oz. of crystallized sulphate of zinc (white vitriol). Mix until dissolved and let it stand half a day in a glass jar.

Copper solution: Two and a half pints of soft water, 4 ozs. of crystallized sulphate of zinc, 8 ozs. crystallized sulphate of copper (blue vitriol). Mix and let stand a few hours in a glass jar.

Dip edge of battery jar for an inch in melted paraffin and let it cool.

Place the parts in jar as in Fig. 111 and pour jar nearly three-fourths full of the zinc solution. Place it at once in the spot where it is to be used and pour in the copper solution.

Insert a glass funnel in the top of a piece of ⅜-inch rubber tubing. Hold funnel so that lower end of the tube will be in the middle of the jar and just a little above the bottom.

Pour in the copper solution slowly until the copper element is completely covered. Place the cell into service immediately.

This cell will show a sharply defined line between the blue copper solution and the colorless zinc solution. This separation of solutions is essential to the cell's health. Leaving the circuit open for any length of time will allow the solutions to mix and spoil the cell.

The action of the cell is such that no hydrogen is permanently formed. The zinc is steadily dissolved into the zinc solution, setting free some hydrogen. This forms with the copper sulphate, sulphuric acid and me-

tallic copper. The sulphuric acid dissolves more zinc, while the copper plates itself on the copper element at the bottom of jar.

The zinc is consumed and the copper plate grows larger.

The effect of continued action is to increase the strength of the zinc solution so that it tends to settle to bottom of jar.

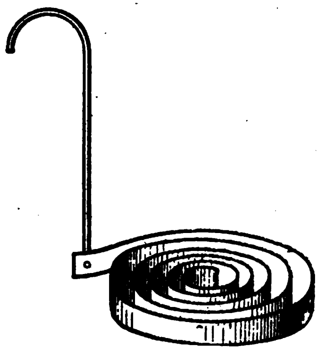


Fig. 112. Long Service Copper Element for Gravity Cell.

The copper being taken out, bit by bit, from the copper solution this latter gets lighter in weight and tends to rise, being pushed up by the zinc solution.

If the blue solution of copper sulphate ever touches the zinc it will copper plate it at once. The cell will then have two copper elements and stop working.

Cells should be given some attention, and clever management will keep a gravity cell working continuously for an almost indefinite time.

As helps in the maintenance of cells two improvements have been made.

Fig. 113. d'Infrevilles Wasteless Zinc.

The form of copper element shown in Fig. 112 is better when heavy currents are not needed. It is a copper ribbon 4 feet long and ½ an inch wide, coiled like a

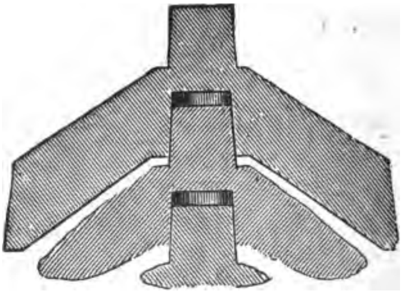


Fig. 114. Using Up Old Zincs.

clock spring. Zincs shaped like Fig. 113 are used until the prongs are all eaten off. A new one is then put in

service and the old one jammed into the bottom of the new one as shown in Fig. 114.

These zincs are hung from a spring clip shown in Fig. 115, which lays across the top of the jar. The stud on the zinc makes a tight friction fit with the hole in the hanger, due to the springiness of the metal.

To keep cells in order a hard rubber syringe with the nozzle at right angles to barrel, holding about a pint, and a hydrometer should be obtained.

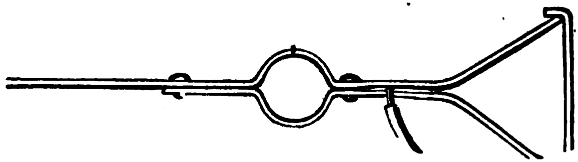


Fig. 115.

The hydrometer (Fig. 116) is a hollow glass float loaded with shot so as to float upright. The heavier a liquid the more of the stem sticks up above the surface.

These hydrometers are graduated on stem in actual specific gravities or in degrees Baume (pronounced Bomay). One with a stem about two inches long graduated from 15° to 40° Baume, or from 1.11 to 1.40 specific gravity, is best for battery work.

The first signs of exhaustion in the cell will be a fading of the deep blue color of the copper solution and a lowering of the line of separation between blue and white liquids.

When this occurs drop in about an ounce of copper sulphate in lumps. Be sure the lumps fall to the bottom.

There will always be a lot of fine powder at the bottom of the copper sulphate barrel. Use this for making up new cells when possible. If too much accumulates for this purpose, make a saturated solution of it in water.

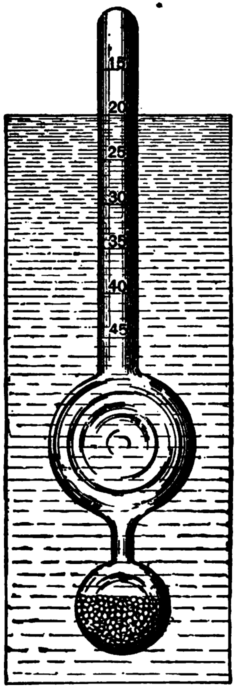


Fig. 116. Hydrometer with Baume Scale.

A saturated solution is one where the water has dissolved all it possibly can of the chemical and leaves some yet undissolved on bottom of jar after repeated stirring.

Place this in cells showing signs of exhaustion in same

way as the copper solution was placed in a newly set up cell.

The zinc solution should be tested as frequently as possible. Once in two weeks is not too often. Drop the hydrometer gently in. Should it read 115 draw some out with syringe and replace by fresh water.

Do not let it go below 1.10. If you have a Baume scale these numbers are 20 and 15 degrees. Throw all the removed zinc in a wooden tub, whether from working cells or from old cells, to be renewed.

Keep half a dozen pieces of metallic zinc in this tub. Any copper in this solution, mixed by cell's action, will turn to a reddish brown curd which can be filtered out. Reduce the clear liquid to 1.10 and use in making up new cells.

Watch your zinc. Should any brown hangers develop on it, detach them with a bent wire and let them fall to bottom of cell.

In time, in spite of all care, the zinc in a cell gets reddish brown all over. It is now time to give a complete overhauling.

Take the cell out of service. Syphon off zinc solution into the tub. Lift zinc out carefully and at once scrub clean with a wire brush. Wash and replace in another cell at once or dry thoroughly and keep dry until needed.

Syphon off the rest of the liquid into another wooden tub and use after filtering as copper solution to make up new cells.

Any lumps of copper sulphate in the bottom take out, rinse and put in other cells.

The mud in bottom of cells and in the zinc solution tub should be dried and sold to brass founders as "battery mud."

The copper plates taken from cells should be kept completely covered with water, wire and all, until needed again.

When they get too heavy and cumbersome sell them, as they are an especially pure form of copper.

Never leave gravity cell on open circuit; the liquids will mix.

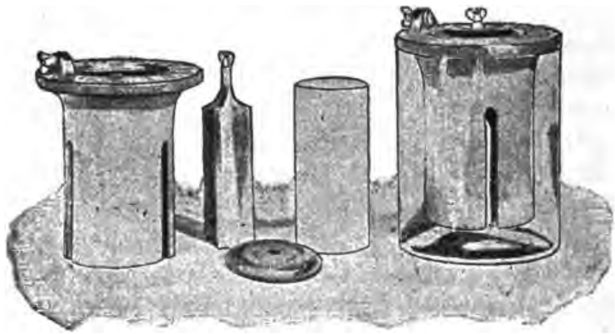


Fig. 117. Fuller Cell.

The Fuller Cell. Semi-closed circuit type, for heavy duty. Long periods of work with little rest.

Polarization cured. Pressure 2 volts, resistance 0.5 ohms. Cell shown in Fig. 117.

These cells are carbon and zinc, and since the chemical which converts the hydrogen to water will attack the zinc, a porous cup is used.

The carbon or the zinc can be placed in the porous cup, but the zinc usually is. A tablespoonful of mercury is placed in bottom of porous cup, the zinc set in and the cup filled with very dilute sulphuric acid (1 acid, 50 water). The carbon is then placed in the outer jar, the

porous cup being also in, and the outer jar filled three-quarters full of battery fluid or electropoin.

This is composed of 4 ozs. of bichromate of soda, 1¼ pints of boiling water, mixed and cooled; then while slowly stirring add little by little 3 ozs. sulphuric acid taken out of a carbon (not diluted). NEVER POUR WATER INTO ACID.

The bichromate of soda has so much oxygen in it that it will turn the hydrogen to water, changing itself to chromate of soda.

When the interior of the porous cup gets dark green colored a cup should be soaked in 1 to 50 acid for an hour and then mercury placed in bottom and zinc set in. Simply take out old cup and insert new one in its place.

The old zinc should be cleaned, porous cup washed and then boiled in water and both placed in stock.

These cells should be left on open circuit when not in use. They are very powerful, but nasty to handle and not as cheap as the gravity cell. When the electropoin gets greenish it soon becomes exhausted, then throw it away. Cold battery rooms or pits affect this cell less than the gravity cell.

Edison-Lalande Cell. This is a semi-closed type with polarization cured. It has a resistance of 0.2 ohms and a very low voltage, 0.7, but is a bull dog for holding on. It will, when set up, start in to deliver a heavy current and keep at it until all its chemicals are used up. It needs no attention and is built so that you can not give any.

When it stops take out the copper and sell it, throwing everything else out. Clean up the jar and fit out again.

The cell uses zinc and oxide of copper plates immersed in a solution of caustic potash. The oxide plate is shown

in Fig. 118 and the complete cell with a glass jar in Fig. 119. Porcelain jars are usually furnished.

The caustic potash comes in sticks sealed up in a tin can.

Place the elements in jar and fill with water to about one inch of the top. Take out the elements and put in the sticks of potash.

Fig. 118. Oxide Plate of Edison-Lalande Cell.

Stir constantly while dissolving, for it gets very hot and might crack the jar. Be very careful not to get caustic potash on your flesh. It not only burns terribly, but makes a wound which is very hard to heal.

If you buy potash by bulk, make the solution up to 1.33 on specific gravity scale or 38° on the Baume scale.

Place the zinc and copper oxide elements in the jar, seeing that they are properly separated by the hard rubber buffers. Pour the bottle of oil over the top of solution and place cover on.

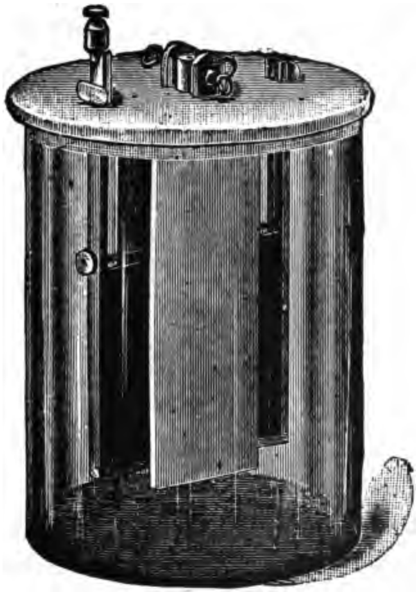


Fig. 119. Edison-Lalande Cell.

If buying oil by bulk, get a heavy paraffin oil which will read 1.46 specific gravity on 48° Baume and pour a ¼ inch layer on each cell.

These are good cells, but any sulphuric acid or caustic potash cell is a nasty thing to handle.

The action of the cell dissolves the zinc, setting free hydrogen, which is changed to water by the copper

oxide, which is reduced to pure copper by giving up the oxygen in it.

The Dry Cell. Shown in Fig. 120 is really a moist cell sealed up water tight with cement or glue.

The can is made of zinc and serves as one element, while a carbon plate or rod is the other. Around the carbon is packed a mixture of powdered manganese dioxide, carbon and flour, while the rest of the can is

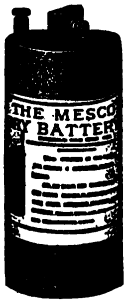


Fig. 120. Dry Cell.

filled with a mixture of plaster, oxide of zinc and flour; the whole being soaked with a solution of sal ammoniac and zinc chloride. Pressure 1.4 volts.

These are very useful for testing, as they can be carried around in a satchel or your overcoat pockets.

Whenever they are used in sets see that their resting place is dry, otherwise the moisture will connect all the zinc cans together and cause them to run down.

The principles on which primary cells work are simple and well understood by most people; yet there are men trying yet to design a cell to do more than is possible.

The best that could be done with a cell using zinc as the dissolved metal is to get one horse-power-hour* per pound of zinc.

There are inevitable wastes, which prevent us doing as well as that, so with coal at 1/4 cent a pound and zinc at 16 cents it is evident that the primary battery will only be used when circumstances force us to use it.

One great waste is Local Action:

Local Action. Commercial zinc or *spelter* contains small particles of carbon and iron which with the zinc they are imbedded in form small *local cells* producing electricity where it cannot be gotten at for use, and the zinc is continuously dissolved whether the cell is on open or closed circuit. In the sal ammoniac batteries sometimes the change in the strength of the solution will cause the zinc to be eaten through at or very near the surface of the solution.

The remedy for this is

Amalgamation. Mercury forms a soft paste or amalgam with all the metals except iron, and will not dissolve carbon. Advantage is taken of this fact and *local action is prevented* by cleaning the zinc with sand paper, washing with dilute sulphuric acid, and while wet rubbing on mercury (quicksilver) with an old brush or a rag tied to a stick. N. B. Mercury is a poison. The zinc becomes bright, covered with a layer of zinc-mercury amalgam; and the particles of iron and carbon are merely covered up and protected from the acid, which cannot corrode the mercury. During the action

* An horse-power hour is the work done by a one horse-power engine running at full load for an hour; or the work done by a 10 H. P. engine running at half load for one-fifth of an hour, etc.

of the cell the zinc dissolves out, and the mercury eats its way into the zinc, reforming the amalgam. When the zinc around the particles is eaten away they fall out to the bottom of the battery jar and do no harm. Zincs for batteries are sometimes cast with 5% of mercury in them. When the zinc is in a porous cup it is a good thing to pour a tablespoonful of mercury into the cup and then set the amalgamated zinc in. With all the precautions that can be taken about 3% of the zinc put in the cell is wasted in local action.

CATECHISM TO LESSON 15.

1. What is an open circuit cell?
2. What is a closed circuit cell?
3. What is polarization?
4. What means are used to prevent polarization?
5. What ways are there of curing polarization?
6. What two materials of ordinary cost make the best cell?
7. How good a cell would zinc and iron in sal ammoniac make?
8. Would the results of a zinc silver combination in sulphuric acid give results worth the cost?
9. What is the name of the wet end of the zinc element? The dry end?
10. What is the name of the wet end of the copper or carbon element? The dry end?
11. Why would not a zinc-copper cell made like a Law cell operate?
12. What cells would work well on a signal circuit closed 98% of the time?

13. What cell would work well on the motor of a signal, current closed 1% of the time?
14. What is Local Action?
15. What is amalgamation of zinc?
16. How are zincs amalgamated?
17. What is a hydrometer?

LESSON 16.

STORAGE BATTERIES.

The storage cell is rapidly pushing the primary battery aside in signal and fire alarm work on account of:

(1) Its high voltage.

(2) Its great current capacity.

(3) The lowering of total battery expense if used for several years.

(4) Its steadiness of action.

Storage cells are used in train lighting to furnish light when train is not in motion and to steady the supply of current.

They are used in some cases to furnish the power to operate switches on locomotives and motor cars.

In power houses they offer a reserve supply of power and act as a steadier of the load on the generators.

The simplest storage cell would be two strips of lead immersed in dilute sulphuric acid. When current is sent through them one plate turns a dark brown color and the other a grey color. After an hour's passage of current reverse the connection and charge the other way. The plates will change color—the grey one becoming brown and the other one grey.

If this charging first in one direction and then in the other be kept up, you will notice that after each reversal of the current through the cell the acid is quiet but soon begins to gas or boil. This is the signal to reverse the current as the cell is charged.

When the cell takes several hours to gas it is in condition to use.

After one of the reversals continue to charge until cell has gassed about fifteen minutes. Remove the charging wires and connect to anything you wish to run. About 70% of the power you put into the cell can now be taken out.

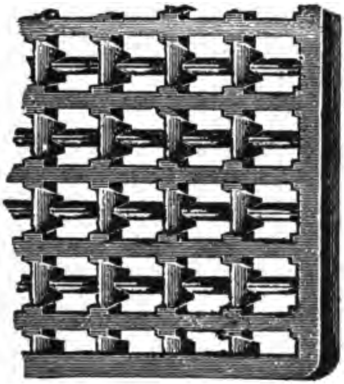


Fig. 121. Lead Grid.

You may now use this as a storage cell, charging it up till it gasses and then using the accumulated electricity as you please.

You always lose 30% but you have the advantages of portability and ability to work when engines are shut down.

In time you will notice that the lead plates become spongy and should the cell be used long enough the plates will finally crumble and break. You will notice that the more spongy the plates become the greater a charge they are capable of holding.

In fact, just before your battery goes to pieces its capacity is the greatest.

To make a commercially practical cell we would proceed thus:

The lead plates would be replaced by grids as shown in Fig. 121 or by grooved plates as in Fig. 122.

Litharge and sulphuric acid is mixed to a stiff paste and the grids or grooved plates plastered with the paste and stood up to dry. This makes a negative plate.

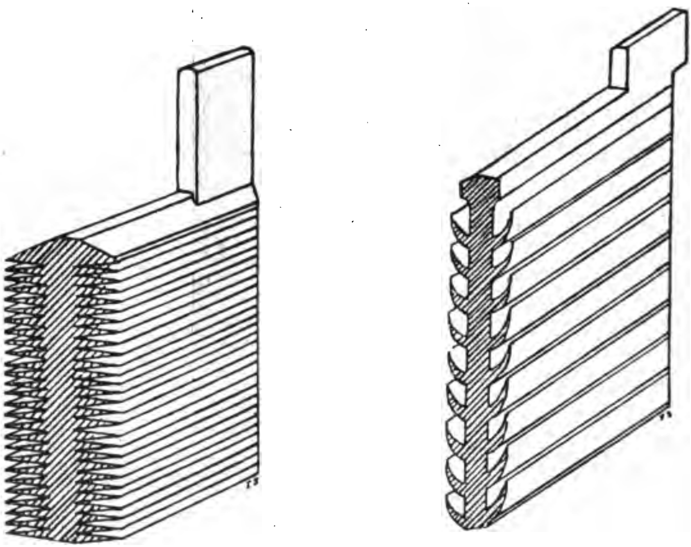


Fig. 122. Grooved Lead Plates.

Using a paste of red lead and sulphuric acid the positive plates are formed in the same way.

The objection to a storage cell using these plates is that after very little use they go to pieces. The changing of the red lead to the brown oxide, and the changing of the litharge to spongy lead is accompanied by a swelling

and shrinking of the material. This loosens up the pasted mass and it begins to fall out.

Most of the ingenuity of inventors has been concentrated on making plates which would hold the active materials firmly and continually.

Perhaps one of the best lead-lead (i. e. lead for both plates) is the Electric Storage Battery Company's Chloride Cell.

Fig. 123. Chloride Accumulator.

This cell is shown in Fig. 123. Its method of manufacture is interesting and is practically as follows:

The first thing is to get finely divided lead which is made by directing a blast of air against a stream of the molten metal, producing a spray of lead which upon cooling falls as a powder. This powder is dissolved in nitric acid and precipitated* as lead chloride on the addition of

*Turned back to a solid.

hydrochloric acid. This chloride washed and dried forms the basis of the material which afterwards becomes active in the negative plate. The lead chloride is mixed with zinc chloride, and melted in crucibles, then cast into small blocks or tablets about ¾ inch square and of the thickness of the negative plate, which according to the size of the battery varies from ¼ inch to 5/16 inch. These tablets are then put in molds and held in place by pins, so that they clear each other 0.2 inch and are at the same distance from the edges of the mold. Molten lead is then forced into the mold under about seventy-five pounds pressure, completely filling the space between the tablets. The result is a solid lead grid holding small squares of active material. The lead chloride is then reduced by stacking the plates in a tank containing a dilute solution of zinc chloride, slabs of zinc being alternated with them. The assemblage of plates constitutes a short-circuited cell, the lead chloride being reduced to metallic lead. The plates are then thoroughly washed to remove all traces of zinc chloride.

A later form of negative plate consists of a "pocketed" grid, the opening being filled with a litharge paste; this is then covered with perforated lead sheets, which are soldered to the grid. The positive plate is a firm grid. composed of lead alloyed with about 5% of antimony. about 7/16 inch thick, with circular holes 25/32 inch in diameter, staggered so that the nearest points are .2 inch apart. Corrugated lead ribbons 25/32 inch wide are then rolled into close spirals of 25/32 inch in diameter, which are forced into the circular holes of the plate. By electrochemical action these spirals are formed into active material, the process requiring about thirty hours; at the same time the spirals expand so that they

fit still more closely in the grids. This form of positive is known as the Manchester Plate.

In setting up the cells the plates are separated from each other by special cherry wood partitions, the perforations being connected by vertical grooves to facilitate the rising of the gases. Sometimes glass rods are used as separators.

There are ten sizes of cell, the smallest containing three plates 3 by 3 inches, and the largest having seventy-five plates 15½ by 30¾ inches, ranging in capacity from 5 to 12,000 ampere-hours, and in weight from 5½ to

Fig. 124. Lead-Zinc Storage Battery.

5,800 lbs. The smaller sizes are provided with either rubber or glass jars, and the larger one with lead-lined tanks.

In the lead-lead cells the negative plates deteriorate in capacity, while the positive plates increase in capacity, with continued use.

To even things up the two end plates are made negative and they then alternate, thus giving one more negative plate per cell.

A lead-zinc cell is made by the United States Battery Co. It is shown in Fig. 124.

The positive plate is of perforated lead sheets riveted together with lead rivets and formed by the slow process of charging and reversal as described in first part of lesson. The negative element is a zinc amalgam which swells up when charged.

This amalgam lies on bottom of jar while the lead element hangs over it.

The pressure given by these cells is a little higher than a lead-lead cell and they weigh less for the same capacity. For signal work they are excellent, while for reserve power use the lead-lead cell is preferred as being better under such severe conditions.

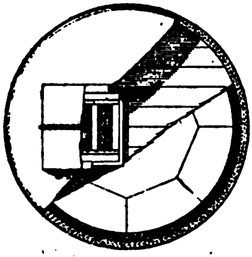
The Edison Cell uses grids of nickel plated iron, the grids being filled with small nickel plated steel boxes which are perforated with very small holes.

The boxes in positive plate are filled with oxide of nickel and pulverized carbon, the negative boxes being filled with oxide of iron and pulverized carbon.

The carbon in each case is merely to render material a better conductor.

A 20% solution of caustic potash is used in a nickel plated steel vessel.

The advantage of this cell is its lightness and ability to stand the most reckless abuse. For railway work it is no better than any other cell and its price puts it out of consideration.



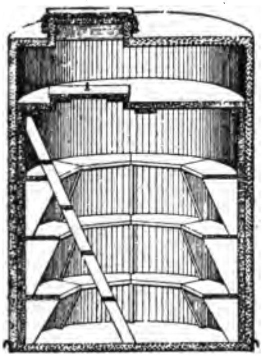


Fig. 125. Top and Inside View of a Concrete Battery Well.

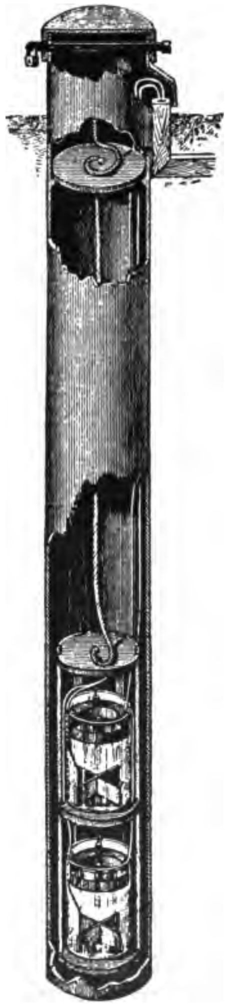


Fig. 126. Battery Chute.

Catechism.

Question 1. What is a storage battery?

Answer. It is a cell somewhat resembling a primary cell, used to store electricity.

Question 2. Does the cell produce electricity or simply store it?

Answer. The chemicals in the cell are not normally capable of producing electricity but by treating them with electric current for some hours they become changed so that they can produce electricity like a primary cell. In fact we might say that a storage battery is a primary cell which, when exhausted, is restored to its original power by application of electric current which renews the chemicals, whereas in the ordinary primary cell we have to buy new chemicals. The gravity cell can be renewed a few times by passage of current, but soon gets in a condition where purchase of fresh chemicals is absolutely necessary.

Question 3. Of what material is the positive plate made?

Answer. Red lead is the real plate, but it is supported by a lead grid.

Question 4. What material is used for the negative plate?

Answer. Spongy lead or litharge, held in a lead grid. Zinc in form of amalgam lying on a copper plate.

Question 5. What fluid is used in jars?

Answer. Dilute sulphuric acid.

Question 6. What is sulphuric acid?

Answer. It is an oily liquid either colorless or with

a very faint yellow tinge. It is sold in carboys* as Oil of Vitriol and should test by hydrometer (Lesson 15) to 1.842 specific gravity or 66 degrees Baume.

To avoid the constant use of the decimal point battery attendants call the strong acid 1842 acid and call water 1000 specific gravity.

Question 7. What is dilute acid?

Answer. It is acid of 1842 strength mixed with pure water. To make 1200 acid take 1 measure of acid and pour into 3 measures of water. For 1400 acid take 1 measure acid and pour into an equal quantity of water. 1200 acid is most used and corresponds to 25° Baume.

Question 8. Is pure water necessary?

Answer. For best results, yes. Distilled water is not so very expensive to make and it pays. Half of the battery troubles are caused by filling up cells with any clean water that is handy.

Even clean water contains chemicals that should not get into the storage battery.

Question 9. Should the diluted acid be cooled before putting in cells?

Answer. It should be thoroughly cooled. Acid should always be diluted the day before you intend to use it. The specific-gravity should be taken after acid has cooled at least twelve hours.

Question 10. Does it make any difference whether 1200 or 1400 acid is used?

Answer. Yes. Acid from 1150 to 1230 is generally used. The stronger the acid the greater the capacity of the battery and the more liable it is to get the disease of Sulphate.

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*Carboys are large glass bottles several feet high and about the same diameter. They are securely boxed to prevent breaking.

Question 11. Why is it that the acid tested in cells is sometimes so high?

Answer. The acid is weakest when cell is discharged and strongest when cell is charged. This is because the acid goes in and out of the plates on discharge and charge.

Question 12. What is meant by a 180 ampere-hour cell?

Answer. It means that the cell in question will give 1 ampere for 180 hours, if it has been fully and properly charged. It might give 30 amperes for 6 hours if it was designed for allowing the flow of such a current.

It certainly would not give 180 amperes for 1 hour as the heat generated would buckle the plates and ruin the battery before the end of the hour.

Question 13. What is the normal rate of a battery?

Answer. As batteries are usually made we may draw 1 ampere from every 10 square inches of positive plate, counting both sides, without over heating.

A cell of 5 positives and 4 negatives, has plates 5x7 inches. What current is it safe to draw? 7x5=35=one side of a plate. Both sides 70 sq. in. 5 plates gives 350 sq. in. Dividing by 10 gives 35 as safe current. This is called the normal rate. In actual practice we usually discharge at about normal rate and hurry the charge by exceeding the normal rate.

Question 14. What harm does this do?

Answer. Wastes money. It costs more to put in 180 A H (ampere hours) quickly than it does slowly.

Question 15. What is an 8 hour rate?

Answer. It means taking 8 hours to charge or discharge the battery. If battery is worked twice as hard it

will charge or discharge in half the time or at a 4 hour rate.

Question 16. What precaution should be taken in a battery room?

Answer. The room must be dry and well ventilated to get rid of the acid fumes. Walls and floors should be of enameled brick and ceiling of white cement. Windows should be white-washed on outside or of ground glass to prevent sun shining on cells and heating them.

The benches cells stand on should be soaked in paraffin. The cells should stand on insulators.

Question 17. How are signal batteries installed?

Answer. In wells like Fig. 125 when there are many. These wells are of sheet steel and concrete, and are about 10 feet high. They are heated when necessary by small oil stoves or by being packed over the top with manure.

When only two or three cells are used the battery chute of Fig. 126 is installed. The chute is of iron pipe and goes down below the frost line. The cells are hauled up by the rope for renewal or charging.

Question 18. Of what material are battery jars made?

Answer. Glass, hard rubber, celluloid, wood with sheet lead lining.

Small cells usually have glass jars as in Fig. 127. Large cells have the lead lined wooden tank as in Fig. 128. Hard rubber and celluloid are expensive. Neither is transparent.

Question 19. How should cells be put in service?

Answer. As soon as electrolyte (acid) is put in the cell it should be charged with one-third its normal rate for 4 hours, then increase to normal rate and continue 20 hours. Cells will now be up to 2.6 volts each.

Drop back to one-quarter normal rate. The voltage of each cell will drop a little. Continue charging up to 2.6 volts again.

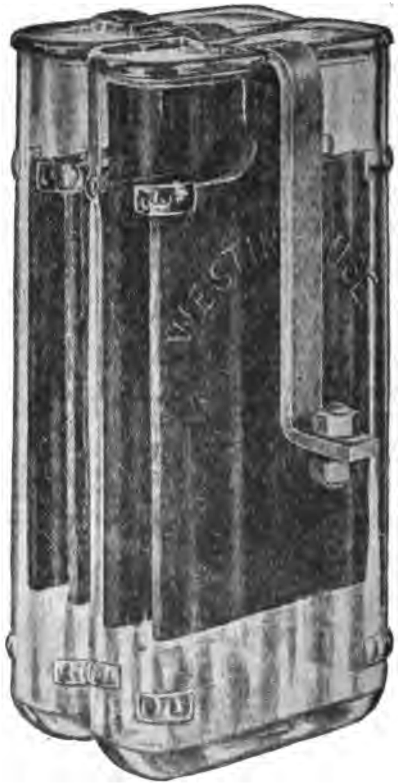

Fig. 127. Form of Storage Battery for Signal Work. Glass Jar.

Question 20. How should cells in service be treated?

Answer. Never discharge below 1.7 volts and 1.8 is better. Charge up to 2.5 volts usually at normal rate.

Once a week give a charge at one-third normal rate till cells read 2.6 volts.

Never let them stand idle with less than 30% of their capacity in them. The fuller a cell the safer it is when idle. When cells are idle charge up to boiling once a week.

Fig 128. Storage Battery in Lead Lined Wooden Tank. Tank Rests on an Insulated Frame.

Do not habitually overcharge cells; it is a waste of money.

The cell is charged when the specific gravity of electrolyte is about 0.025 higher than when discharged.

Bubbles of gas are given off freely when cell is fully charged, because material of plate is no longer able to take up the oxygen and hydrogen which tend to be set

free by the electrolysis;* these bubbles give the electrolyte the appearance of boiling, and often they are so fine that the liquid looks almost milky-white, particularly in a cell which has not been very long in use.

The color of the positive plates varies from a light brown on active parts to a chocolate color when fully charged, and to nearly black when overcharged. The negatives vary from pale to dark slate color, but they always differ in color from the positives. This indication of the amount of charge is learned by experience, but is quite definite after one becomes familiar with a particular battery.

Do not discharge too rapidly, it wastes money. A cell whose normal rate of discharge is 100 amperes for 8 hours, can be discharged at the rate of 400 amperes in one hour, but never at the rate of 400 amperes for 2 hours. You see the rapid discharge is inefficient and you only get half as much energy out of cell as you could have obtained at a slower rate.

Question 21. Do storage batteries wear out or depreciate?

Answer. Yes, it will take 10% of the cost of a battery every year to keep it in repair.

Question 22. How should a battery be put out of commission or laid up?

Answer. If, for any reason, the battery is to be but occasionally used, or the discharge is to be at a very low rate, a weekly freshening charge to full capacity at normal rate should be given. It sometimes happens that a storage battery is put out of commission for a long period. In such cases the procedure is as follows: First the battery is given a complete charge at normal

*Lesson 17.

rate, then the electrolyte is siphoned off into carefully cleaned carboys (as it may be used again), and as each cell is emptied it is immediately refilled with pure water. When the acid has been drawn from all cells and replaced with water, the battery is discharged until the voltage falls to or below one volt per cell at normal current; when this point has been reached the water should be drawn off. In this condition the battery may stand without further attention until it is again put into service, which is accomplished in the same manner as when the battery was originally started. If during the discharge, when the water has replaced the electrolyte, the battery shows a tendency to get hot (100 F.) colder water should be added.

Question 23. What troubles occur in batteries and what are their remedies?

Answer. The most serious troubles which occur in storage batteries are sulphating, buckling, disintegration, and short-circuiting of the plates. These can usually be avoided, or cured by proper treatment if they have not gone too far.

SULPHATING.—The normal chemical reaction which takes place in storage batteries is supposed to produce lead sulphate on both plates when they are discharged, their color being usually light brown and gray, due to the presence of lead oxide, on the positive plate. But under certain circumstances a whitish scale forms on the plates. Plates thus coated are said to be "sulphated." This term is, however, somewhat ambiguous, the formation of a certain portion of ordinary lead sulphate being perfectly legitimate, but the word has acquired a special significance in this connection. A plate is inactive, and practically incapable of being charged,

when covered with this white sulphate, as it is a non-conductor.

The conditions under which this objectional sulphating is likely to occur are as follows:

(a) A storage battery may be left discharged for some time, even though the limits have not been exceeded.

(b) A storage battery may be overdischarged, that is, run below the limits of voltage specified, and left in that condition for several hours.

(c) The electrolyte may be too strong.

(d) The electrolyte may be too hot (above 125 F.).

(e) A short circuit may cause "sulphating" because the cell becomes discharged (on open circuit) and during charging it receives only a low charge compared with the other cells of the series. A battery may become overdischarged or remain discharged a long time on account of leakage of current due to defective insulation of the cells or circuit, or the plates may become short-circuited by particles of the active or foreign substances falling between them.

(f) By charging at a very low rate, for example, one-thirtieth of normal.

Sulphating may be removed by carefully scraping the plates. The faulty cells should then be charged at a low rate (about one-half normal) for a long period. In this way, by fully charging and only partially discharging the cells to about 1.9 volts at the 8-hour rate, for a number of times the unhealthy sulphate is gradually eliminated. When the cells are only slightly sulphated, the latter treatment is sufficient without scraping; but with cells that are very badly sulphated, the charge should be at about one-quarter the normal rate for three days.

Adding to the electrolyte a small quantity of sodium sulphate, or carbonate,* which later is immediately converted into sodium sulphate, tends to hasten the cure of sulphated plates by decomposing or dissolving the white sulphate. This is not often used, as a cell should be emptied, thoroughly washed, and fresh electrolyte added before the cell can be used again.

Sulphating not only reduces the capacity of lead storage batteries, but also uses up the active material by forming a scale which falls off or has to be removed. It also produces the following trouble:

BUCKLING, or warping of a plate, may be caused by too great expansion of the active material, which strains the ribs of the containing grid: or by uneven action on the two surfaces; for example, a patch of white sulphate on one side of a plate will prevent the action from taking place there, so that the expansion and contraction of the active material on the other side, which occurs in normal working, will cause the plate to buckle. This might be so serious that it would be impossible to straighten the plate without breaking or cracking it; but, if taken in time, it may be accomplished by placing the warped plate between boards, and subjecting it to pressure in a screw or lever press. Striking the plate is objectionable, because it cracks or loosens the active material; but, if it should be necessary to straighten a plate when no press is available, a wooden mallet may be used very carefully, with flat boards laid under and over the plate. Buckling is caused by an excessive rate of charging or discharging, as well as by sulphating.

DISINTEGRATION.—Some of the material may become loosened or entirely separated from the plates, as

*Sal-soda; common washing soda.

a result of various causes. The chief of these is sulphating, which forms scales or blisters that are likely to fall off, thus gradually reducing the amount of active material and the capacity of the cell. Buckling also tends to disintegrate the plates. Contraction and expansion of the active material may take place in normal working, and are increased by excessive rates or limits of charging and discharging. This constitutes another cause of disintegration, particularly in plates of the Faure type, containing plugs or pellets of lead parts. The fragments which fall from the plates not only involve a loss of active material, but are also likely to extend across or gather between the plates and cause a short circuit.

The positive plates are far more susceptible to and injured by these troubles than the negatives. The former are also more expensive to make, therefore it is to them that special attention should be directed in the management of storage batteries.

SHORT-CIRCUITING may be caused by conditions previously stated, and also by the collection of sediment at the bottom of the containing well. The short-circuiting caused by the dropping in of foreign matter, or bridging by the active materials, is prevented by the use of glass, rubber, or wooden separators. The short-circuiting of plates by the formation of sediment is prevented, or the chances of it are decreased, by raising the plates so that they clear the bottom of the containing cell. In small batteries this clearance is about an inch; in large cells it is considerable, being about 6 inches, and on account of the weight of large-sized plates they are supported at the bottom by glass frames running lengthwise through the cell.

The sediment should be watched carefully, and when

it reaches a depth of an inch or more at the center of the cells it should be removed. The usual method is to take out the plates, syphon the electrolyte off carefully, and then flush out the tanks until all the sediment is removed. If syphoning cannot be resorted to, a pump may be used, either of glass or of the bronze rotary type.

TROUBLES FROM ACID SPRAY.—A battery will give off occasional bubbles of the gas at almost any time; but when nearly charged the evolution becomes more rapid. These bubbles, as they break at the surface, throw minute particles of acid into the air, forming a fine spray which floats about. This spray not only corrodes the metallic connections and fittings in the battery room, but is also very irritating to the throat and lungs, causing an extremely disagreeable cough. Glass covers are sometimes placed over cells to prevent the escape of fumes, but this is not advisable as the glass becomes moist and will collect dust, thus forming a conducting surface over the battery.

Attempts have been made to do away with the spray by having an oil film over the electrolyte, but this interferes with the use of hydrometers, and sticks to the surface of the plates when they are removed, thus increasing the resistance when they are replaced. Another plan consists in spreading a layer of finely granulated cork over the surface of the liquid, but while this does not interfere with the hydrometer, it makes the cell look dirty. The general practice is to depend almost entirely upon ventilation to get rid of the acid fumes, in fact, even forced ventilation is used. A blower forces fresh air into the room, which is provided with a free exhaust. In connecting up the cells, it is advisable to use lead-covered copper cables, as this covering protects the

copper, and prevents the formation of copper salts which might drop into the cell and contaminate the electrolyte.

THE PURITY OF THE ELECTROLYTE is very important, and great care should be taken to insure it. The electrolyte may have nitric acid present when "formed" (Plante) plates are used, and some chlorine, when "Chloride" negatives are used. In addition, iron may be present due to the water or acid, if the sulphuric acid is made from iron pyrites; it may also be present, owing to the corrosion of iron fittings near the cells, some of the scale falling into the electrolyte. Similarly the copper salt formed from the connections by corrosive action may fall into the cell. Mercury may also be present due to the breakage of hydrometers or thermometers. Other foreign substance might be present, but those named are the most harmful.

Nitric acid, even in exceedingly small quantities, causes disintegration, as the supporting metal grid of the plate is destroyed.

Chlorine has a similar effect.

Iron, mercury, and copper produce local action, and thus decrease the efficiency and ultimately the life of the cell.

The electrolyte should be tested about once a week for these impurities, and if any of them are present, it should be drawn off and renewed. When nitric acid is found, it is advisable to flush the cell with pure water.

Question 24. How are batteries connected to line?

Answer. Usually they are "floated" on line, meaning that the battery is always connected and charged when load is light and discharged when load is heavy. This gives the battery the least possible work to do and keeps

it well charged at all times. Fig. 129 shows this. Switches are provided to cut off battery or to cut off dynamo and let battery run the lights. Usually both switches are closed as shown.

Question 25. What is end cell regulation?

Answer. If 700 volts are wanted at station 300 cells would give 750 volts when fully charged and 510 volts when at their lowest safe limit.

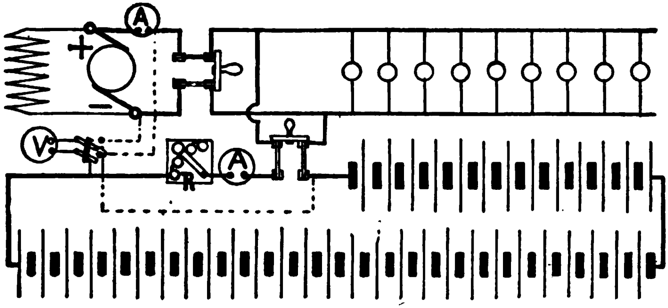

Fig. 129. Diagram of Connections for a Storage Battery to Float on Line.

If 280 cells were connected permanently and 130 extra cells arranged so as to be cut in at the end of the string of 300 cells a few at a time, then when cells were down to 1.7 volts we would have 410 in service and have full voltage.

Question 26. What is booster regulation?

Answer. A booster is a dynamo whose field magnets are excited by the current going out to the lines. Hence when the battery is being worked the hardest the booster dynamo furnishes the highest voltage which is added to that of the battery.

As the battery voltage drops the attendant regulates the field rheostat of the booster so as to add enough voltage to keep the combined voltage up to the regular voltage.

Question 27. Are batteries much used in railroad work?

Answer. Yes. Every electrically lighted train has a storage battery to run things when the train is still.

Many motor cars have storage batteries to operate the controlling devices.

Power houses have batteries to run things in case of accident.

The New York Central has five batteries, each giving 2,250 amperes for one hour and others give 3,000, 3,750 and 4,000 amperes each. The whole set can run the entire electrical division of the railroad for an hour in case of a mechanical break down.

ELECTRICALLY OPERATED TURN TABLES.

In the yards of all our large railroads the hand operated turn table has gone out of use or ought to go at once.

Locomotives are so heavy, some weighing 175 tons and a few even 200 tons, that it requires too many men to turn, especially in winter.

In busy junctions and terminals the hand turning, being so slow, is a great source of congestion and delay.

A steam "donkey" or single wheeled locomotive is occasionally used to turn the table, being attached to one end and running on the same rails as the wheels of the turn table.

The equipment consists of a small vertical boiler, a steam engine, a water tank and a coal bin. Water and coal must be brought to the table and ashes taken away.

In many places a licensed engineer is required by law. If some old locomotive engineer has the job, it is wasting a valuable man on a poor job, as his knowledge of railroading and the road should be utilized where they will be of service.

It has often been suggested that a pipe be run from the station heating plant or the shop boilers. Steam from this pipe, which should run underground to the center of the table pit, would be taken through a pivoted slip joint to the "donkey."

In this case, owing to the length of pipe, the engine would have to run on hot water most of the time.

The electric motor is just the thing to operate a turn table and they are rapidly coming into general use.

Where a terminal has been electrified the electric turn table goes without saying, but it will pay any road to install an electric turn table even if they must buy power from the local electric light company.

The same dynamos which furnished 125 or 250 volts for lighting the station or shops can operate the turn table motor.

The regular equipment would be a small railroad motor with the ordinary gearing, a rheostatic controller and a circuit breaker, the whole being mounted on a single wheeled truck. This constitutes an electrical "donkey." Such a turn table is shown in Fig. 130.

Where a large number of engines must be handled quickly, a regular turn table operator should be employed and a cab built over the "donkey" for his protection.

There are many cases, however, where it is feasible for the locomotive fireman to operate the turn table. In such a case the controller should be installed in middle of table at one side, and the cab is not essential.

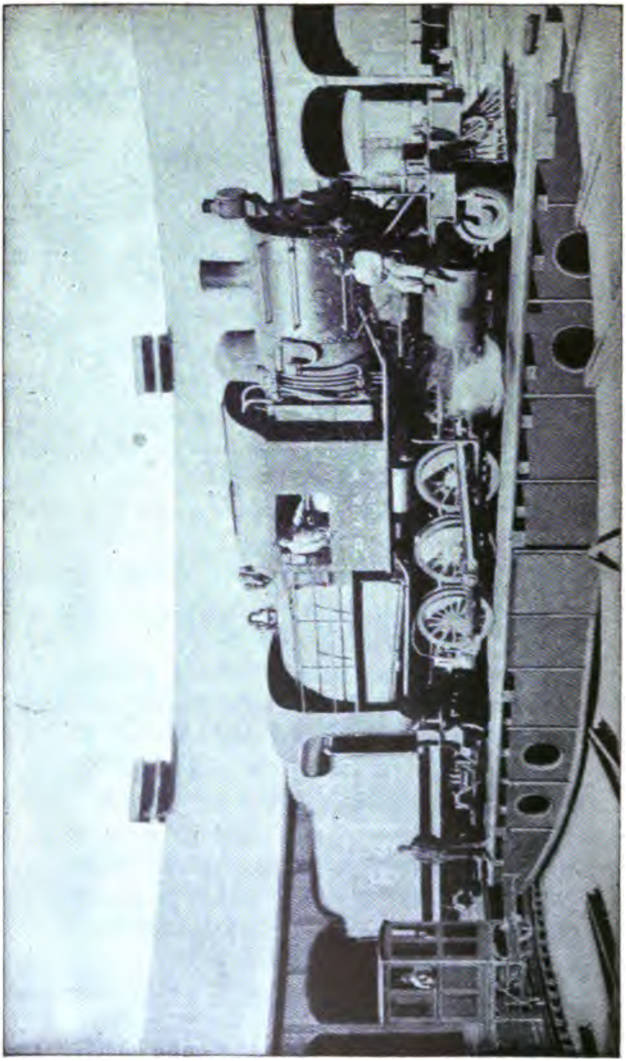

Fig. 130. Turn Table with Donkey.

The details of the "donkey" are well shown in Fig. 131, while Figs. 132, 133, 134 give all the information of the equipment that would be required. Note that the rails can be sanded in both directions.

The cost of a turn table "donkey" as in Fig. 130 is about $1,000.

Single wheel truck....................	$ 350
Electrical equipment	500
Installation	150
	$1,000

This is based on the assumption that the railroad buy the truck from a truck builder, do the mechanical work in their own shops and let the electricians install the electrical equipment when received from the manufacturers.

The turn table shown in Fig. 135 is of the "draw bridge" type. The table rests on a heavy cradle which turns on a train of small wheels.

A large stationary gear as shown is engaged by the pinion of the vertical motor shaft.

You will notice that a "donkey" drives by friction like a locomotive so that ice on rails, or oil will reduce traction and make sand necessary. The "draw bridge" type drives positively by a gear.

Whatever type is used the ordinary street railway motor is best adapted to the purpose. It is completely enclosed and water and dust proof.

The conditions of frequent starting and large momentary overloads makes the direct current series motor the best. If only alternating current is obtainable the compensated series motor will give good service. If only

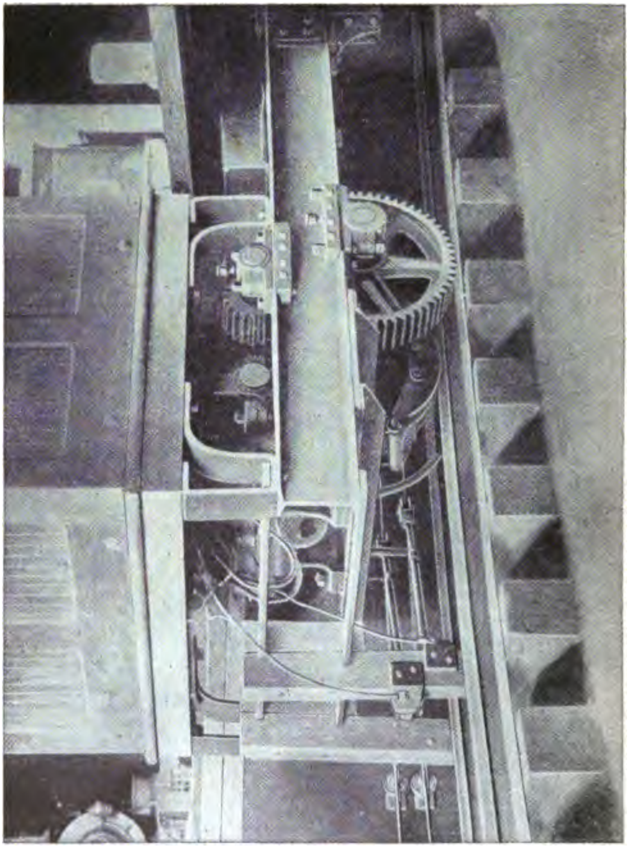

Fig. 131. Under Part of Donkey.

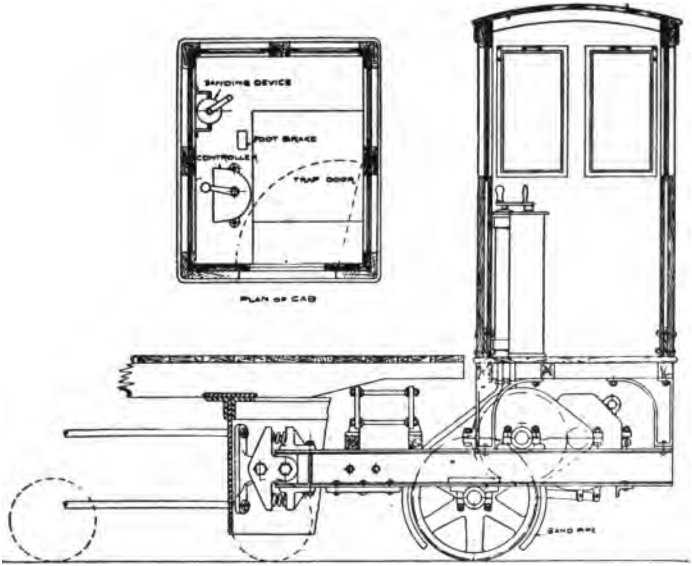

Fig. 132. Side View of Donkey and Plan of Interior of Cab.

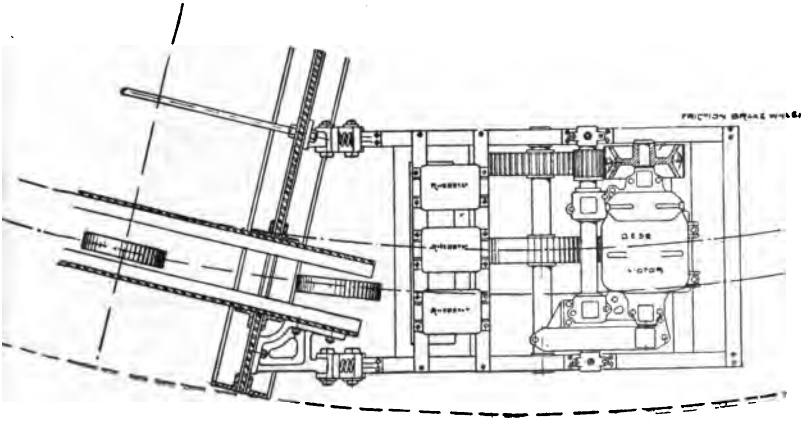

Fig. 133. Plan of Under Part of Donkey.

multiphase alternating current can be obtained an induction motor will do the work better than hand or steam. The induction motor should be of the definite wound armature, collector ring, external resistance type, and be designed for speed variation. (See Lesson 27.)

In any case the motor must be designed and constructed to stand rough use and even positive abuse.

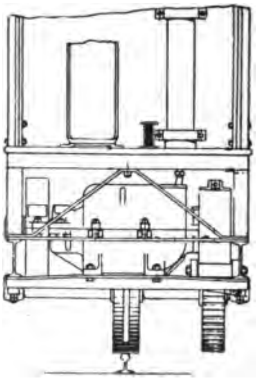

Fig. 134. End View of Under Part of Donkey, Gear Wheel of Motor on Right, Single Drive Wheel in Center.

The motor is usually provided with feet, and in place of the car axle an intermediate shaft is substituted so that there is a double reduction gearing. Both sets of gears run in a gear case filled with oil or soft grease.

The armature shaft of motor is extended at the end opposite the pinion and a hand brake fitted. Sometimes this is set by a wheel and sometimes by a weight or a spring and is released by a foot lever.

The controller is like a street car controller except that it has no separate reverse wrench.

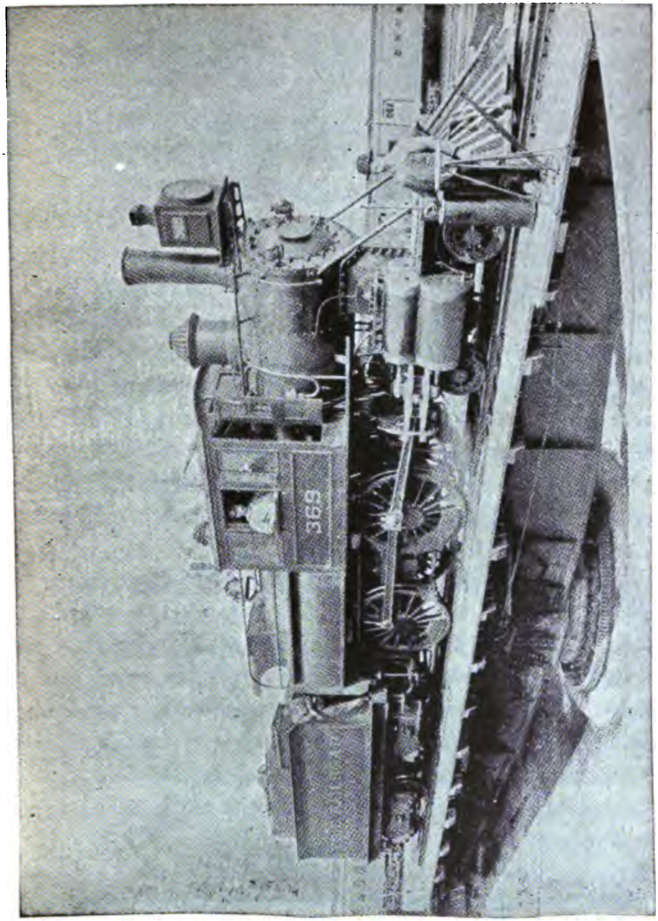

Fig. 135. Draw Bridge Type of Turn Table.

The handle being in center, power is off; moving it to right turns table to right, to the left turns table to left.

The resistances are like those on a street car.

The circuit breaker serves as a switch and protects from serious overloads.

The advantages of electrically operated tables are: Low cost of maintenance and operation; speeds up, moves and stops quickly; perfect control of speed; consumes power only when work is done.

Perhaps time saving is its greatest advantage. In a certain terminal the new round house was built to accommodate twice as many locomotives as the old one. The electrical turn table served this round house with less delays than the hand table caused when serving the old house.

The actual power to turn a 60-foot table with a 100-ton engine on, is from 8 to 12 H. P. The speed of operation was one turn in 40 seconds. At the moment of starting the power ran up to about 20 H. P.

It is for this reason that a 20 H. P. railway motor is installed.

A 10 H. P. motor of regular type would operate the table, but not as well. The reason is not because the 20 H. P. railway is more powerful than a 10 H. P. regular motor, for strange to say they are of about equal power. (See Lesson 27.)

The railway motor is best suited to the work and should be installed.

No time should be wasted in trying to balance engines on the table; in fact, the 8 H. P. result was obtained with engine slightly out of balance; 9 H. P. was when engine was balanced and 12 H. P. when much out of balance.

In one yard where the electric table turned 300 locomotives a day, the cost of the power used was less than the cost of hauling the coal to the steam donkey previously employed. It would have been utterly foolish to waste time in balancing engines to try to save a little power.*

In this yard the actual cost of turning a locomotive by electric power from their own shop, was 1.4 cents. This was obtained by averaging the total expense for six months' use of the table. Had this power been purchased from the local electric light company, it would have cost them 1.9 cents per locomotive.

There are three good ways of bringing the power into the turn table:

The best way is to lead the wires from underground up to a pair of cast iron rings and have brushes in the table to collect the current.

When center pivots are solid and the under bracing complicated this cannot be done.

For a turn table of this description the method shown in Fig. 131 is good.

Two trolley wires, in spans of 6 or 8 feet, are placed around the wall of the pit, supported by trolley hangers of the "toggle" type, ordinarily used in electric mine haulage. Short trolley poles are flexibly attached to the "donkey," so as to allow a horizontal movement on account of the variation in the trolley wires and a vertical movement to accommodate the tilting of the table. This scheme is

*While extravagance is to be deplored, false economy is equally foolish, spending a dollar to save 98 cents is not business nor religion. Railroad officials are not the only ones gone crazy on "economy" or "efficiency." I shall refer to this at other places.

simple and inexpensive, and in practice has operated in a very satisfactory manner.

In some places, on account of the possibility of the pit being flooded, neither of the arrangements described

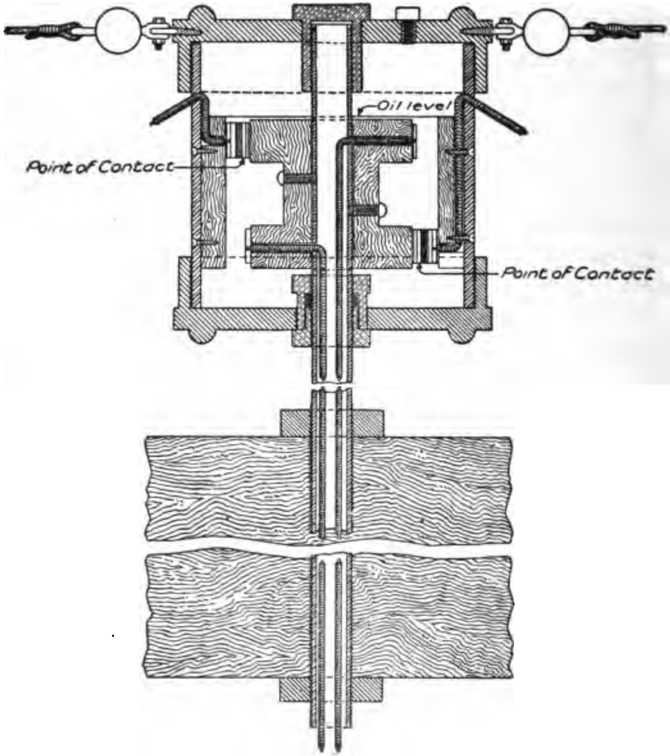

Fig. 136. Overhead Contact for Turn Table.

above is practicable and it becomes necessary to collect the current from above the turn table. A very ingenious arrangement for this purpose has been used on a turn

table where the pit occasionally fills with sea water. A light arch was built over the center of table to support directly over pivoted point the device shown in Fig. 136. The case is a piece of 8-inch steam pipe with a regular cap fitting screwed on each end. A bearing is set in at the top and a stuffing box at the bottom.

The case is held stationary by wire rope guys attached to regular trolley road insulators and the two electric wires enter the case and end in copper brushes insulated by a hard wood shell.

A piece of 1-inch gas pipe turned smooth on the outside at one end is fastened to the table. Its upper end revolves in the bearing of the case and takes most of the weight of it. The guys merely steady it and prevent rotation. The gas pipe revolves in the oil tight stuffing box at bottom of case. A hard wood spool on the gas pipe carries two copper rings which collect current and from which the two wires run down inside the pipe to the turn table.

The case is filled with oil which serves a triple purpose: it lubricates, insulates, and prevents the gases and steam from the locomotive from running contacts and insulation.

LESSON 17.

ELECTROLYSIS.

The word electrolysis means a loosening up by electricity done in a liquid.

There are three classes of liquids:

(1) Do not conduct electricity, as oils, petroleum products.

(2) Simply conduct like mercury, melted metals.

(3) Conduct and are loosened up so that the different constituents separate and the constituents of the same kind collect together.

Dilute acids (1 part acid and 20 parts water); solutions of metallic salts (copper sulphate, ammonium chloride); melted chemicals; are in the third class.

Liquids of the third class are called Electrolytes and the process Electrolysis.

Now when an electric current is passed through these solutions, they split up into parts, one part being liberated at the point where the current enters, and the other part where it leaves the liquid. If, for instance, we pass a current through water, we find oxygen gas being liberated where the current enters the water, and hydrogen gas where it leaves. The conductors that lead the current into and out of the liquid have been called the electrodes (or electricity doors). The leading-in electrode is called the anode (or entering door), and the leading-out one the cathode (or exit). Therefore we say oxygen is liberated

at the anode, and hydrogen at the cathode. If the solution contains a metal it is always liberated at the cathode.

The plus wire of circuit is attached to anode and negative wire to the cathode.

When a metal is dissolved in a dilute acid and the water boiled away the solid substance left is called a salt.

If the metal sodium is dissolved in weak muriatic acid and the water boiled away common table salt is left behind. If this is dissolved in water again we can by electrolysis separate it into the soda and muriatic acid again.

Cryolite is a compound with a great deal of aluminum in it. By melting it and while liquid passing current through it the aluminum is collected at the cathode.

The pieces of the electrolyte produced by electrolysis are called ions.

HOW ELECTROLYSIS TAKES PLACE.

Electricity is an invisible something known only by its effects. It can be moved from place to place through the air as Marconi has shown, or it can be more accurately and more cheaply transferred by copper wires. How the air or the copper wire conducts the electricity we do not know.

When electricity is transferred through a liquid we know that certain kinds of little particles of the substances in the liquid carry the electricity across from the anode to the cathode and stay there and certain other kinds of particles collect about the anode, for there is a transfer of electricity in both directions.

Unless these little particles are present the liquid will not conduct. If they are present the liquid conducts and

while conducting the loosening process goes on and more particles (ions) are produced to keep up the conductivity of the liquid.

ELECTROLYSIS OF WATER.

Take a glass of boiled and filtered water (it would be better if it were distilled water). Bring the + and — wires from a 3-cell battery to the glass and fasten strips of platinum foil to the ends by wrapping on wires. Bend the wires up and over the edge of glass and let platinum strips hang in water. Do not let the copper wires get even wet, much less in the water. An ammeter would show no current passing because the pure water has no ions in it. Now pour in a teaspoonful of sulphuric acid and the water begins to conduct (due to presence of ions) and electrolysis commences.

The water is composed of hydrogen and oxygen in the proportion of 2 to 1, and the electrolysis allows these gases to escape into the air so that after a while all the water will be turned to gas.

To a railroad man electro plating and destruction of water and gas pipes are the two important things.

ELECTRO PLATING.

Electro-plating and chemical-plating are often mixed up in people's minds.

If you thrust a pen knife blade or a key into the copper sulphate solution used in a gravity cell, the knife is instantly copper plated by chemical action. If a sheet of iron, sprinkled with sal ammoniac is dipped in a bath of melted zinc it is chemically plated and is called galvanized

iron. Electricity had nothing to do with either of these platings.

As we know that the metals are dissolved into the solution at the anode and deposited at the cathode, we may electroplate an article with copper in the following way:

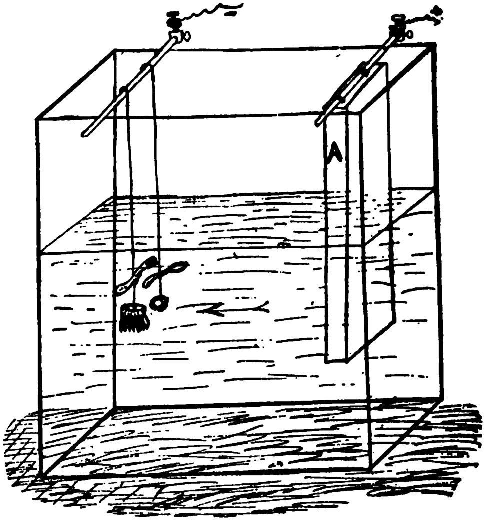

Fig. 137. Electro-plating Cell.

Make a bath of 1 gallon water, 10 oz. potassium cyanide (deadly poison), 5 oz. of copper carbonate, and 2 oz. potassium carbonate.

Place in a glass or wooden tub, connect to positive wire a slab of copper (Fig. 137), and to negative wire the thoroughly cleaned articles. The passage of a current of low voltage will plate copper on the articles.

Brass may be electro-plated on iron castings. This is a cheap and nasty substitute for a solid brass casting.

Impure ores of copper, scrap copper, old telegraph and electric light wires in which there is always more or less solder, and copper mixed with other impurities, may be purified by electrolysis, the cathode being a plate of pure copper, the bath a solution of sulphate of copper, and the anode the impure metal. The pure copper replaces the exhaust from the bath, and the impurities fall to the bottom of the tank. Recovered copper thus deposited is extremely free from impurities, and is used for electrical conductors where low resistance is required.

ELECTROLYTIC CORROSION.

When the current has passed through motors it returns to the power house by many paths, some of which are: Rails of the track, return feeders between rails, elevated railway structures, waterpipes, gaspipes, cables of telephone wires, Edison tubes, adjacent streams of water.

Let us consider the water and gaspipes and the cables. The current going into these is positive and when finally the current leaves them to go to the earth plates of the power house, if the ground is the least bit moist, metal is dissolved and taken away. In this way holes have been eaten in gas and water mains, and the sheathing of cables destroyed. The return current has a habit of leaving the pipes at each joint and coming back into pipe on the other side. This causes corrosion at every joint.

This electrolytic corrosion is frequently the cause of law suits against the railroad companies.

To reduce the evil and to be able to show in case of

suit that every possible precaution has been taken the company should:

Thoroughly bond the track rails at every joint.

Run a bare copper wire along between the rails and connect each rail of the track to it.

Whenever a pipe or cable is found to be in danger of corrosion, run a wire from negative pole of station to the pipe and make a well soldered connection.

It is evident that alternating current will not cause corrosion for it is rapidly reversing in direction.

Main line tracks will have far less trouble with corrosion than branches, and city extensions, belt lines, etc., which run through streets crowded with pipes and cables.

CIRCUITS.

An electric current is so called because it is the thing through which the electricity passes or makes its circuit around through the different pieces of apparatus and machinery.

The word circuit is used in connection with many other words as: series circuit, parallel circuit, short circuit, A. C. circuit, etc. These will all be explained in the following lessons.

A dead circuit must be made live before it can deliver power, and where so delivering it is called a loaded circuit.

Every loaded circuit has Conductance, Resistance, Insulation, Pressure and Current which are explained in the following lessons.

The habit of referring to circuits as lines has grown so that the words are almost interchangeable.

We ought to be more accurate and use the words in this manner.

When a wire starts from the power house and returns again we have a circuit. When we speak of a part of this circuit we say "the line between Chicago and Hinsdale."

When the wires run from a power house to a sub-station we may call it "the line." Of course there is an electric circuit there but we are always thinking of it as if current only flowed from power house to sub-station, and speak accordingly.

When one side of the circuit is composed of rails, earth, etc., we always speak of the copper part as the "line" and the rest of it as the "ground."

Fig. 138 shows several kinds of circuits and corresponding effects.

Taking the top part of the figure with the solid lines. Starting from the terminal of the battery we have a series circuit through the magnet, lamp, resistance, electrolytic tank and back to the terminal of the battery.

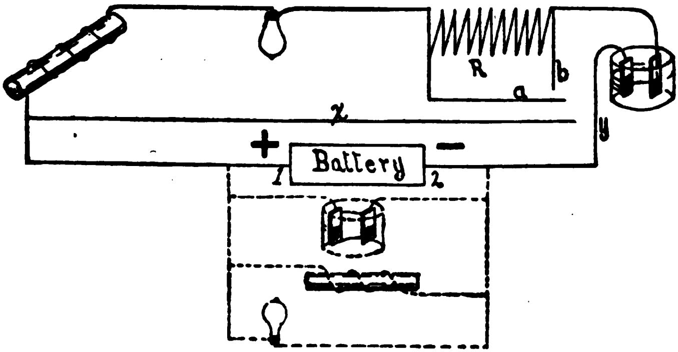

Fig. 138. Diagram of Circuits.

In such a series circuit the same current must pass through each of the pieces of apparatus. If the circuit had all lamps, or all electro-plating tanks this would perhaps be satisfactory, but since a lamp takes one-half to one ampere and the plating bath 10 amperes and upwards, it is evident that such a circuit will not work at all when different kinds of apparatus are in it. Either the plating bath won't work or the lamp will be burnt out in a few minutes.

Another objection to a series circuit is that should we wish to stop the flow of current through the resistance R, we cannot open the circuit by a switch as that would cut the current off from all the rest of the apparatus. A short-circuiting switch must be installed as shown at a, b. When the ends of these wires are connected by a switch, a shunt circuit is formed around R and the shunt will carry the current when R is removed. The shunt circuit must be made of large enough wire to carry the current formerly carried by R without over heating.

Such a short circuit of a part of a series circuit causes no trouble at all but a short circuit of the whole of a series circuit must be made more carefully. The resistance of the wires x, and y forming the short circuit should be very low when a series dynamo is used and verv high when a battery is used.

A very low resistance short circuit on a series dynamo stops the generation of current, and a very high resistance short circuit on a battery stops it generating current.

A high resistance short circuit is always referred to as a shunt, and the words short circuit reserved for low resistance ones.

Looking at the dotted part in Fig. 138 we have two, mains running from the battery and branches running across between mains; the branches containing the apparatus.

The mains and branches form parallel circuits and the apparatus is said to be installed in parallel or multiple.

Several distinct advantages are gained by the parallel system.

Each piece of apparatus can draw as much current as it needs without interfering with other apparatus.

The current may be cut off from any of them by opening a switch in its branch without affecting the remaining branches.

Short circuits (i. e. low resistance) anywhere in a parallel circuit will cause considerable damage.

Parallel circuits are fed by shunt dynamos or alternators. A short circuit on a shunt dynamo causes it to generate an enormous current and may destroy the apparatus short circuited and the dynamo's armature. Alternators do not produce such large currents when short circuited so in this case it is the apparatus short circuited that suffers most.

When each branch of a parallel circuit contains several pieces of apparatus in series, the whole is called a series parallel circuit.

Suppose we now learn how electricity flows through circuits.

In hydraulic, pneumatic or steam engineering, the indications of the pressure gauge are of the utmost importance to the engineer; in fact, he is always considering and asking about the pressure, and does not trouble himself about the water, air, or steam, for none of these would be of any use to him unless they existed under a certain head or pressure. It is simply the pressure under which they exist that gives to them their working power.

In a similar way the electrical engineer is always concerned about the electrical pressure; he does not talk or think much about the electricity, but the electrical pressure is always in his mind as being of the first importance.

The hydraulic engineer measures his pressure in pounds per square inch, that is to say, his unit of pressure is that exerted by a pound weight. The electrical engineer's unit of pressure is called the volt (from Volta, an Italian electrician), the consideration of which we will leave for a future lesson. It is owing to this pressure that a current of electricity flows around a conducting circuit. No current could possibly flow unless there was a difference of electrical pressure in the circuit, in the same way that no water would possibly flow through a water conductor unless there existed a difference of pressure.

Instead of calling it the electrical pressure, we might call it the electricity-moving force, or the electro-motive force, or, for brevity, the E. M. F., which is the term most commonly applied to the electrical pressure; thus we speak of the E. M. F. of a circuit as being equal to so many volts.

It would perhaps be well to point out here the engineer's meaning of pressure.*

We may exert a pressure and still have no resultant motion; as, for example, suppose a man applies a pressure (a moving force) at one end of a table, which would of itself be able to move the table along the floor; if now a boy pushes at the opposite end and in the opposite direction, it is certain that the table would not be moved as rapidly as before, providing the man pushes with the same force throughout, while if another man takes the place of the boy and pushes with equal force to the man opposite to him, the table would not be moved at all, although there is now a greater pressure being

*This illustration is taken from Mr. Tyson Sewall.

applied to the table than in the original case. It will therefore be seen that the result obtained does not depend on the pressure, but on the difference of pressure, and in all cases where pressure is spoken of it is the difference of pressure that is meant.

Returning to the experiment with the table, we have just seen that before the table can be moved we must provide a table-moving force, but when this is provided it does not follow that the table will move even then—it all depends on the resistance offered. We can imagine a very heavy table, with rough feet, standing on two rough boards, and the man applying a moving force to it but producing no movement; whereas when the floor has been smoothly planed he may be able to move it slowly, and by fitting wheels or casters to the feet of the table he may be able to move it rapidly with the same moving force.

We see that the rate of movement of the table depends partly upon the table-moving force applied and also in part upon the resistance offered by the boards on which the table stands. It is directly proportional to the former and inversely proportional to the latter. That is to say, if we double the moving force while the resistance remains the same, the rate of movement of the table will be doubled, and if we keep the moving force the same and halve the resistance, the rate of movement of the table will be doubled. This could be stated thus:

$$\left.\begin{array}{l}\text{Rate of move-}\\ \text{ment of table}\end{array}\right\} \text{is proportional to } \frac{\textit{table-moving force}}{\text{resistance.}}$$

Therefore the rate of movement of the table is a thing entirely dependent on two other things, and in try-

ing to find its value we have to ask, first, what is the moving force available? and second, what is the resistance offered? The same applies to water moving in pipes and this is perhaps a better analogy to the electrical case. We say there is a current of water flowing through the pipes, but this current is flowing simply because there is a difference of pressure between the two ends of the pipes, and as the pipes offer a certain resistance, while these two things remain constant, the strength of the current will remain constant also. If we desire to alter the rate of flow (the current), we must alter either the water-moving force (the head) or the resistance (the tap). We can now see why the engineer is not concerned so much about the current; he may want a certain current to flow, but he gets it by seeing either to the water-moving force, or to the resistances, or to both.

If we now apply this electricity we find the same ideas in the mind of the electrical engineer. If he desires a certain current he asks himself, "What E. M. F. (electro-motive force) have I available?" and then, "What resistance must I have in the circuit?" and he makes all alterations in the current strength by adjusting the one or the other, or both, to suit. If the circuit has a fixed resistance then he cannot alter the current flowing round it except by proportionally altering the E. M. F., that is to say, if he wishes to have twice the current strength he must put twice the E. M. F. into the circuit. If the E. M. F. has a fixed value, then he cannot alter the current without altering the resistance of the circuit, thus—if he wishes to double the current strength he must halve the total resistance of the circuit.

All the so-called generators of electricity, dynamos, batteries, etc., are simply devices for producing and maintaining an E. M. F. Some dynamos produce high E. M. F.'s from 2000 to 10000 volts and even higher, while battery cells produce low E. M. F.'s from 1 to 2 volts only.

To make the analogy between the water system and the electrical system more correct, we should suppose a closed circuit of pipes, as shown in Fig. 139, completely filled with water, having a rotary pump P in the circuit, and furnished with a tap R a pressure gauge PG, and a current gauge C G.

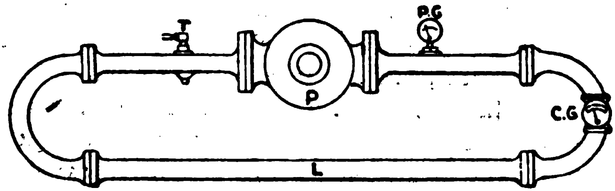

Fig. 139. Simple Hydraulic Circuit with Gauges.

Suppose now we turn on tap T and start the pump working, the pressure gauge will indicate a difference of pressure in the circuit, and the current gauge will indicate a current, flowing round the circuit.

In this case we are not generating water, we are simply putting into motion the water that was already there, and this is done by creating a difference of pressure by means of the pump, and by providing a conducting circuit. If we stop the pump, the two indicators will point again to zero, but there is just the same amount of water there as we started with, there has been no consumption of water.

In the same way we have to think of an electrical circuit (Fig. 140). The dynamo D is simply a device for producing a difference of electrical pressure, and is put into the circuit to act exactly as the pump does in Fig. 139 if we switch on S, which is comparable with turning on the tap in Fig. 139, and start the dynamo working, the pressure gauge (called the voltmeter) VM will indicate a difference of electrical pressure or an E. M. F., and the current gauge (called an ampere-meter, or for brevity an ammeter) will indicate a current flowing round the circuit. In this case we are not generating electricity, but simply putting into motion electricity that was already there.

Going back to Fig. 139, suppose we turn off the tap T and keep the pump working, then the current meter will indicate no current, but the pressure gauge will indicate a slightly higher pressure than before. Here we have a water-moving force, but the resistance in the circuit is now exceedingly great, consequently no current can flow.

Similarly in Fig. 140 if we switch off, still keeping the dynamo running, the voltmeter will show a slightly higher pressure, while the ammeter will indicate no current. Here again we have the one essential for a flow of electricity round the circuit, but not the other, for in switching off we have introduced into the circuit an enormous resistance.

It will be noticed that we have referred throughout to the current as being not the movement of the table, or the flow of water or electricity, nor yet the quantity of water or electricity moved, but as the rate of movement. Fifty gallons of water is not a current of water, but 50 gallons per minute is a statement of the rate of flow, and

consequently is a statement of the current strength. A current is the rate of flow.

Let us return again to our water circuit (Fig. 139) and examine it more closely. Imagine the system to be quite full of water, and remember that water is a practically incompressible fluid. If now we have our pump at work with the tap turned off, we shall have a difference of pressure between the two sides of the pump but no current. The moment we turn the tap on the current

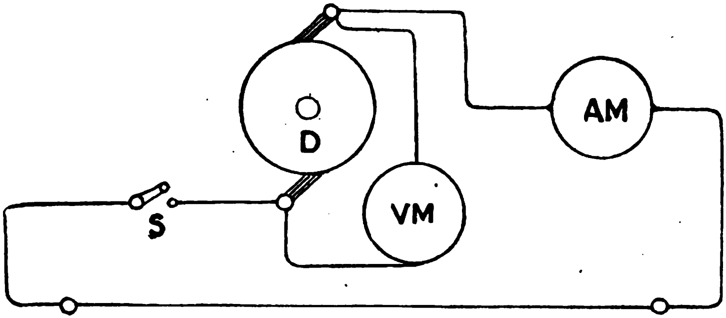

Fig. 140. A Simple Series Circuit, with Instruments.

will flow, but this current will be everywhere in the circuit of the same strength, it will not be strongest at the pump and get weaker as we go round the circuit, but will instantly have the same strength everywhere, and the current does not get used up in going round the circuit.

This is exactly the case with the current in Fig. 140. If the dynamo be at work we have an E. M. F. in the circuit, but while the switch is off no current can flow. The moment we switch on there is a current in the cir-

cuit which is everywhere of the same strength, not stronger near the dynamo, and getting used up as it goes round the circuit, but of the same strength everywhere in the circuit.

It is evident that flow of current is regulated by pressure and resistance of circuit so that

$$\text{Current} = \frac{\text{Resistance}}{\text{Pressure}}$$

using the principles taught in Formulas Page 210 we get two other forms of this rule

Pressure $=$ Current $\times$ Resistance

$$\text{Resistance} = \frac{\text{Pressure}}{\text{Current}}$$

A man named Ohm first noticed this rule and it is called Ohm's Law in his honor.

Let us now consider a few problems on the Ohm's Law.

1. The E. M. F. in a simple circuit (Fig. 140) is 100 volts, the resistance of the whole circuit is 50 Ohms. What current will flow through the circuit?

$$\text{Ohm's law says, current} = \frac{\text{E. M. F.}}{\text{Resistance}}$$

$$\text{Therefore in this case C} = \frac{100}{50} = 2 \text{ amperes.}$$

It must be fully realized by the student that while the E. M. F. remains at 100 volts, and the resistance remains at 50 ohms, the current in that circuit will be 2 amperes, no more and no less. It is impossible for any other strength current to flow.

2. The resistance of the circuit being reduced to 10 ohms, while the E. M. F. is kept at 100 volts, what is now the strength of the current?

$$\text{Again current} = \frac{\text{E. M. F.}}{\text{Resistance}}$$

$$\text{Therefore } C = \frac{100}{10} = 10 \text{ amperes.}$$

3. It is found that when an E. M. F. of 100 volts is applied to a circuit, a current of 25 amperes flows. What is the total resistance of the circuit?

$$\text{Resistance} = \frac{\text{E. M. F.}}{\text{current}}$$

$$\text{Therefore resistance} = \frac{100 \text{ volts}}{25 \text{ amperes}} = 4 \text{ ohms.}$$

4. In the same circuit we find that by twisting upon itself some of the wire of which it is composed, the current increased to 50 amperes. What is now the resistance of the circuit, and how much resistance has been cut out by so twisting up the wire?

Again by Ohm's law—

$$\text{Resistance} = \frac{\text{E. M. F.}}{\text{current}}$$

$$\text{Therefore resistance} = \frac{100}{50} = 2 \text{ ohms.}$$

It had four ohms previously; we have therefore cut out $4 - 2 = 2$ ohms.

5. In a circuit of 20 ohms resistance, a current of 5 amperes is flowing. What is the E. M. F. in the circuit?

By Ohm's law—

The E. M. F. = Current $\times$ Resistance.

Therefore E. M. F. $= 5 \times 20 = 100$ volts.

6. What is the E. M. F. in a circuit whose resistance is equal to 10 ohms when a current of 20 amperes flows through it?

E. M. F. = Current $\times$ Resistance.

E. M. F. $= 20 \times 10 = 200$ volts.

We have now to consider circuits other than the simple circuits just described, known as divided circuits or parallel circuits.

Fig. 141 represents a simple circuit in which the principal resistance consists of a conductor A of 50 ohms resistance; the remainder of the circuit consists of a dynamo capable of generating the E. M. F. of 100 volts, and thick connecting wires joining it to the ends of A.

If we neglect for the present the small resistances of the dynamo and connecting wires, then the current flowing is

$$C = \frac{E}{R} = \frac{100}{50} = 2 \text{ amperes.}$$

Suppose we now join the points C and D with another conductor B exactly similar to A, as in Fig. 142. Will the current through the dynamo be greater or less than before? And will it make any difference to the current flowing through A?

Let us see. The circuit B having the same resistance as circuit A conducts just as well, hence twice as much current can flow between C and D, as flowed before. It is evident that the resistance offered is now half what it

was. In Fig. 141 it was 50 ohms, in Fig. 142 it must be 25 ohms, by Ohm's law the current through the dynamo has doubled, for $C = \frac{E}{R} = \frac{100}{25} = 4$ amperes; 2 amperes through A, and 2 amperes through B.

To make this quite clear, let us take our water analogy again. Fig. 143 represents a water circuit similar to our last electrical circuit. If the pump be working continuously, maintaining a difference of pressure between its ends, then with *T* turned on and *t* turned off, we

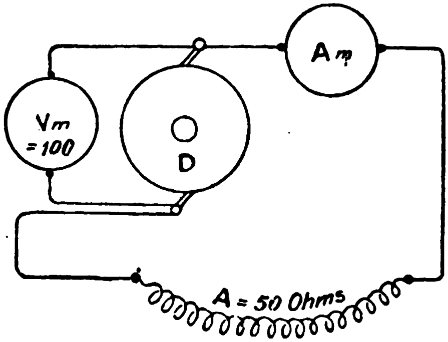

Fig. 141. A Series Circuit.

should have a flow of water round the circuit through A, which would offer the principal resistance of the circuit, and the current gauge would indicate a certain current flowing through the pump. If now we turn on tap *t*, we open up another path for the water to flow in, and consequently, as water will flow in B just as easily as in A,

the resistance to the passage of water from C to D would be halved, and the current gauge would immediately indicate twice the former current. The two pipes in parallel are really equivalent to one pipe of twice the internal sectional area. The same thing would apply to 3, 4, 10, or any number of similar pipes joined between C and D; the resistance would be reduced to ½, ¼, or 1/10 its former value, with a corresponding increase in the current flowing through the pump.

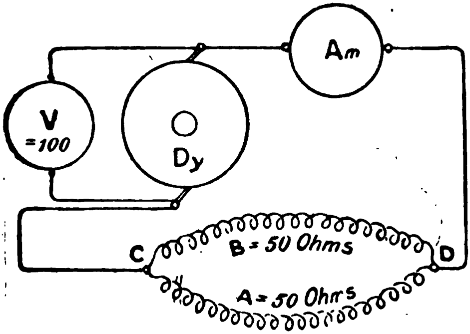

Fig. 142. Parallel Circuits.

It must be understood that there is no increase in the current flowing through any individual pipe when others are connected across. The current in A, Fig. 143, for instance, would remain practically constant throughout providing the pump maintained the same difference of pressure.

It is in this way that we must look upon the electrical current in Fig. 142. The more similar wires we join between C and D, the more are we increasing the con-

ductivity between these two points, and the less is the resistance becoming, but providing the dynamo maintains the pressure, no alteration would take place in the value of the current in any individual conductor. Each separate conductor would act according to Ohm's law, and each being joined to points, maintained the same difference of potential, and each being of the same resistance, each must have the same strength of current flowing through it.

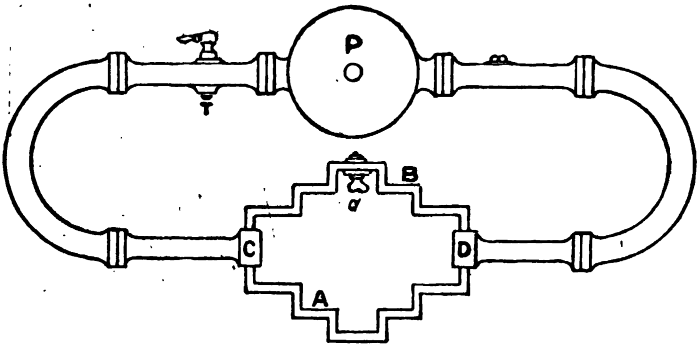

Fig. 143. Hydraulic Circuit with By-pass.

Effects of Current.

Imagine a circuit like Fig. 144 containing in order:

1. A galvanometer or current meter.
2. An electromagnet.
3. An apparatus for electrolysing water or a gas voltameter.
4. A copper plating bath or copper voltameter.

5. A vessel containing a coil of wire submerged in water, and surrounded with a box of sawdust to prevent the radiation of the heat.

6. An incandescent lamp.

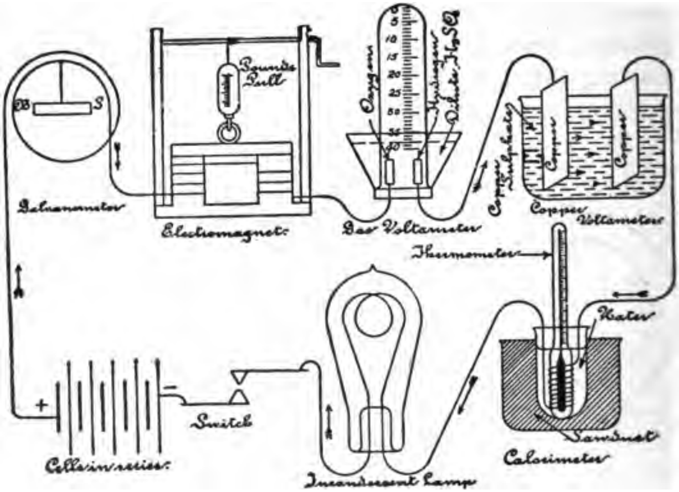

Fig. 144. The Different Effects of Current.

When the current is flowing you will observe the following effects:

1. The needle is deflected.
2. Armature of magnet is attracted and held.
3. Water is turned to oxygen and hydrogen gases.
4. The cathode is copper plated.
5. The thermometer rises.
6. The lamp gives light.

Now let us examine the size of each of these effects, measuring them in the most suitable units, and then let the current be changed from its original value to say twice and then three times that value and see how the size of the effect varies.

The *Galvanometer* gives readings of 10, 15, 17 degrees, so that the effect of a given current varies according to whether it is the only current passing or one of many equal currents.

The Electro-magnet gives 9 lbs. pull, then 11 lbs., and finally 11½ lbs.; so that evidently the attraction of a magnet does not increase in the same proportion as the increase of current in its coils.

In the *Gas Voltameter* we find that double the current electrolyses double the quantity of water, and three times the current, treble the water. The same is true of the *Copper Plating Bath.* The amount of metal deposited is exactly proportional to the current and the time. A given current deposits 0.0026 pounds of copper per hour; double the current will deposit 0.0052 pounds, treble the current 0.0078 pounds.

The thermometer in the *Calorimeter* has risen very rapidly. The original current made it rise 1/10 of a degree a second, twice the current gave a rise of 4/10 degrees and thrice the current gave 9/10 degrees rise.

Since	1 x 1	equals	1
and	2 x 2	"	4
and	3 x 3	"	9

And since the numbers 1, 2 and 3 represent the currents; and 1, 4, 9 the heat produced, we say that the heating is proportional to the square of the current.

(The product obtained by multiplying a number by itself is called the square of that number).

The extra amount of *Light* obtained by increasing the current is small and does not increase regularly. The first increase in current adding 3 candle power, and the next increase added 4 candle power, while the next would have probably added 6 candle power.

Looking back over these current effects it will be seen that the electrolysis or electro-chemical effect is the only one that is regular in a simple manner, so we choose the amount of *copper* or *silver plating* done as the test for the size of the current flowing. We decide that the unit of current shall be called an

AMPERE, which is the current depositing 0.0026 pounds of copper or 0.00887 pounds of silver per hour. Although a certain current may be lighting a lamp, if that current were made to silver plate and deposited 0.00443 pounds in ½ hour, we should call it an ampere.

The original Edison Meters were nothing but zinc plating baths put into the customers line and by the amount of plating done the amount of current drawn by the lamps was known.

Modern meters are either galvanometers marked to show amperes or are small motors with a cyclometer attachment to record the ampere-hours.

An ampere-hour is one ampere for one hour, half an ampere for two hours, etc.

LESSON 18.

RESISTANCE.

Every conductor offers more or less opposition to the flow of electricity and we call the opposition Resistance.

In order to compare the resistance of different materials some standard of resistance must be agreed upon. All electricians and engineers have settled on the

OHM. The unit of resistance is the ohm, which is the same resistance as is offered by a mercury conductor made in this way: Take 0.0318 of a pound of pure mercury and pour it into a glass tube which is exactly 41.88 inches long, and of uniform size of bore. The mercury must exactly fill the tube when both are at a temperature of 32 degrees Fah. Try different sized tubes of the same length (41.88 inches) until one is found to be exactly filled. Then the resistance offered by this conductor to the passage of electric current is called one ohm. Remember that the temperature must always be 32 degrees.

Mercury is selected because it is a liquid and because its resistance is high and so the tube is not inconveniently long.

To measure all resistances the ohm is used, but to express very small resistances the microhm is used. It is one millionth of an ohm.

To express very high resistances the megohm is used, It is one million ohms. It is abbreviated meg.

A telephone engineer would refer to a resistance of 0.00385 ohms as 3850 microhms. Ohms×1,000,000= microhms.

In speaking of the resistance between the two track rails measured across the ties an engineer would probably say 47.5 megs instead of 47,500,000 ohms.

Ohms÷1,000,000=megohms.

Laws of Resistance.

The resistance varies with the nature of the material. The metals are good conductors, cotton and dry goods very poor conductors, while silk, porcelain, shellac, oils, mica, paraffin, and dry air are so poor that we call them insulators.

If we take a piece of wire having a known resistance, and cut it into two equal lengths, we find on measuring that each piece has just half the resistance of the former piece, hence the law is twice the length, twice the resistance.

Stated mathematically it is—

The resistance of a given wire of uniform section is proportional to its length.

But the resistance also depends on the cross section of the wire. If we take three wires of the same material, but with cross sections, of 1, 2 and 3 circular mills,* if the first one has 1 ohm resistance, the others will have ½ and ⅓ of an ohm resistance.

Hence the greater the area of wire's cross section the less the resistance.

The resistances are inversely proportional to their cross sectional areas.

---

*See further on in Lesson.

It must be remembered that the cross sectional area is obtained by squaring the diameter. If the diameters of two wires are 3 and 6 mils, their areas are 9 and 36 circular mils and the resistance of the first wire is 4 times as great as the second, because the area is only ¼ of the second.

The resistance of conductors also varies very largely with the nature of the material used. For instance, if we take three different wires, all the same length, and the same sectional area, but one made of copper, another of iron, and the third of german silver, their resistances would be in the ratio of 1:6:13. It is useful to remember these figures as being approximately correct, for the three metals named are in great demand in electrical engineering.

German silver made of 2 parts copper, 1 of zinc and 1 of nickel, is an extra high resistance metal, and is useful when we need a lot of resistance in a small space. The resistances used to aid in the starting of traction motors are usually of cast iron.

Stated briefly, the longer the piece of material the higher is the resistance, and the greater its cross section the lower the resistance. The rule being:

$$\text{Resistance in ohms} = \frac{\text{Material x Length}}{\text{Cross Section.}}$$

The number representing the materials are the ohms resistance of a piece 1 foot long and 1 mil in diameter.

Copper 10.8 Iron 63.4
Aluminum 17.2 Mercury 128.3
German Silver 586.2

For Length insert the number of feet and for Cross Section put the square of the diameter in mils (thousandths of an inch).

For example: Find the resistance of 9000 ft. of iron wire 0.2 inch in diameter.

Material: Iron 63.4. Length in feet 9000

Diameter in mils 200. Squared 40000

$$\text{Resistance in ohms} = \frac{63.4 \text{ x } 90000}{40000} = 14.26$$

This rule only applies to round wires but may be changed so as to apply to rectangular conductors.

$$\text{Resistance} = \frac{\text{Material x Length}}{\text{Area x } 1.27}$$

Area being the area of the cross section of rod in square mils.

An increase in the temperature increases the resistance of the metals, but they each have their own way of increasing, some faster than others.

The resistance of copper increases a little less than ¼ of 1% for every degree Fahr. and iron increases a little more than copper. Mercury increases about 1/40 of 1% per degree.

Wire Measurement.

The diameter of a round wire or bar is always measured in mils. A mil is a thousandth of an inch.

The area of round wires is measured in Circular mils. The number of circular mils is found by squaring the diameter measured in mils.

This is a far better way of measuring than the mechanics way of square inches, but cannot be applied to rectangular pieces of material.

To make matters as simple as possible the electrician measures the two dimensions of the cross section in mils and obtains the area (by multiplying them together) in square mils. This he converts at once to circular mils by multiplying by 1.27. Then having circular mils he can apply formulas.

The mil-foot is used in formulas and is handy as a comparison of resistances.

A piece of round material 1 foot long and 1 mil in diameter is a mil-foot.

Resistance and Conductivity.

If we take a piece of wire whose resistance is 1 ohm, and apply an E. M. F. to the ends of it, we find that it is able to conduct electricity. We might say that this piece of wire has unit conducting power, or unit conductivity, as well as unit resistance. If we take another piece of the same wire, but twice the length of the former piece, it will have twice the resistance, that is, it will conduct electricity only half as well as the former piece, consequently we should say this piece of wire has resistance of 2 ohms and a conductivity of ½. Again, if we take a wire having a resistance of 10 ohms, then it will conduct electricity only 1/10 as well as the piece having 1 ohm. Therefore we should say its conductivity is 1/10, and so on.

We thus see that the conductivity of a substance is the reciprocal or the reverse of its resistance. If the resist-

TABLE OF DIMENSIONS OF PURE COPPER WIRE.*

No. B. & S.	Diam. Mils.	Area.		Weight and Length, Sp. Gr. 8.9.		
		Circular Mils.	Square Mils.	Lbs. per 1000 feet.	Lbs. per Mile.	Feet per Pound.
0000	460.000	211600.0	166190.2	640.73	3383.04	1.56
000	409.640	167805.0	131793.7	508.12	2682.85	1.97
00	364.800	133079.0	104520.0	402.97	2127.66	2.48
0	324.950	105592.5	82932.2	319.74	1688.20	3.13
1	289.300	83694.5	65733.5	253.43	1338.10	3.95
2	257.630	66373.2	52129.4	200.98	1061.17	4.98
3	229.420	52633.5	41338.3	159.38	841.50	6.28
4	204.310	41742.6	32784.5	126.40	667.38	7.91
5	181.940	33102.2	25998.4	100.23	529.23	9.98
6	162.020	26250.5	20617.1	79.49	419.69	12.58
7	144.280	20816.7	16349.4	63.03	332.82	15.86
8	128.490	16509.7	12966.7	49.99	263.96	20.00
9	114.430	13094.2	10284.2	39.65	209.35	25.22
10	101.890	10381.6	8153 67	31 44	165.98	31.81
11	90.742	8234.11	6467.06	24.93	137.65	40.11
12	80.808	6529.94	5128 60	19.77	104.40	50.58
13	71.961	5178.39	4067.07	15.68	82.792	63.78
14	64.084	4106.76	3225.44	12.44	65.658	80.42
15	57.068	3256.76	2557.85	9.86	52.069	101.40
16	50.820	2582.67	2028.43	7.82	41.292	127.87
17	45.257	2048.20	1608.65	6.20	32.746	161.24
18	40.303	1624.33	1275.75	4.92	25.970	203.31
19	35.890	1288.09	1011.66	3.90	20.594	256.39
20	31.961	1021.44	802.24	3.09	16.331	323.32
21	28.462	810.09	636.24	2.45	12 952	407.67
22	25.347	642.47	504.60	1.95	10.272	514.03
23	22.571	509.45	400.12	1.54	8.1450	648.25
24	20.100	404.01	317.31	1.22	6.4593	817.43
25	17.900	320.41	251.65	.97	5.1227	1030 71
26	15.940	254.08	199.56	.77	4.0623	1299.77
27	14.195	201.50	158.26	.61	3.2215	1638.97
28	12.641	159.80	125.50	.48	2.5548	2066.71
29	11.257	126.72	99.526	.38	2.0260	2606.13
30	10.025	100.50	78.933	.30	1.6068	3286.04
31	8.928	79.71	62.603	.24	1.2744	4143.18
32	7.950	63.20	49.639	.19	1.0105	5225.26
33	7.080	50.13	39.369	.15	.8015	6588.33
34	6.304	39.74	31.212	.12	.6354	8310.17
35	5.614	31.52	24.753	.10	.5039	10478.46
36	5.000	25.00	19.635	.08	.3997	13209.98
37	4.453	19.83	15.574	.06	.3170	16654.70
38	3.965	15.72	12.347	.05	.2513	21006.60
39	3.531	12.47	9.7923	.04	.1993	26487.84
40	3.144	9.88	7.7635	.03	.1580	33410.05

* 1 mile pure copper wire 1-16 inch. diam. = 13.59 ohms at 15.5° C. or 59.9° F.

1 circular mil is .7854 square mil.

ance of a conductor be 50 ohms, its conductivity is 1/50. A name has been given to the unit of conductivity which is easy to remember. Seeing that the conductivity is the reverse of resistance, the name of the unit of resistance (ohm) has been reversed for that of conductivity. Thus a wire of 1 ohm resistance has 1 mho conductivity. A wire of 75 ohms resistance has a conductivity of 1/75 mho, while a wire of ½ ohm resistance has a conductivity of 2 mhos.

Of course it will be understood that if conductivity is the reciprocal of resistance, then resistance is also the reciprocal of conductivity, one the reverse or reciprocal of the other. Therefore a wire of 1/50 mho conductivity has a resistance of $\frac{1}{\frac{1}{25}} = 50$ ohms.

Resistances in Series and in Parallel.

When resistances are in series we add their values together to get the total resistance but when they are in parallel the resistance of the group, called joint resistance, is less than the smallest and must be calculated in a certain manner.

Turn back to Fig. 142. A can conduct electricity across between A and D its conductivity being 1/50 mho, that is, it will conduct electricity across only 1/50 as well as a resistance of ohm. But we have now got two paths, each with a conductivity of 1/50 mho, so the two together can conduct electricity across twice as well as one of them, for now we have a conductivity of 1/50+1/50 =1/25 mho. We have already seen that resistance is the reciprocal of conductivity, therefore the resistance between C and D is now $\frac{1}{\frac{1}{25}}$ =25 ohms. But it was 50

ohms before we joined the second wire across, so that we have reduced the resistance to half its former value.

If there should be resistances in series with those in parallel figure the joint resistance of the set in parallel and then figure the rest as if that joint resistance took the place of the parallel group and everything were in series.

Consider Fig. 145. Here we have C and D joined by two wires, A having a resistance of 50 ohms, and B having a resistance of 25 ohms.

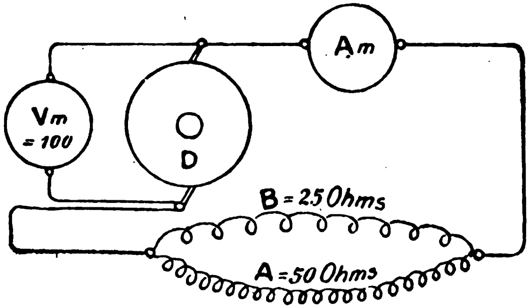

Fig. 145. A Divided Circuit.

Now we have seen that A has a conductivity or conducting power$=1/50$, similarly B has a conductivity$=1/25$, and therefore the two together have a conductivity of $1/50+1/25=3/50$ mho. The resistance between C and D being the reciprocal of the conductivity

$$\text{is } =\frac{1}{\frac{3}{50}}=\frac{50}{3}=16.6 \text{ ohms}$$

(less than the smallest resistance).

The current flowing through the dynamo now is—

$$C=\frac{E}{R}=\frac{100}{16.6}=6 \text{ amperes.}$$

Again, imagine C and D to be connected by three wires, A=50 ohms, B=25 ohms, and G=10 ohms. Then the conductivity between

$$\text{C and D}=\frac{1}{50}+\frac{1}{25}+\frac{1}{10}=\frac{1+2+5}{50}=\frac{8}{50} \text{ mho,}$$

and the resistance between

$$\text{C and D}=\frac{1}{\frac{8}{50}}=\frac{50}{8}=6.25 \text{ ohms}$$

(again less than the smallest resistance joining C and D).

Of course the combined resistance must be less than that of the smallest resistance between the points, for if G were there alone, that part of the circuit would have 10 ohms resistance, and the addition of B and A, though larger than G, is only diminishing the resistance between these points by opening up other paths for the passage of electricity.

Q. 1. What is the resistance of four wires in parallel of 2, 5, 10, and 20 ohms respectively?

The combination has a conductivity of—

$$\frac{1}{2}+\frac{1}{5}+\frac{1}{10}+\frac{1}{20}=\frac{10+4+2+1}{20}=\frac{17}{20} \text{ mho,}$$

and their combined resistance in parallel

$$=\frac{1}{\frac{17}{20}}=\frac{20}{17} \text{ ohms.}$$

Q. 2. Two mains are carrying current for a group of twenty lamps; each lamp has a resistance when incandescent (white hot) of 160 ohms, and they are all joined in parallel. What is the resistance between the two mains.

Here all the resistances are equal and the total resistance is 1/20 of one of them or $160 \div 20 = 8$ ohms.

If we have only to deal with *two* resistances in parallel, it will be easier and quicker to make use of this rule:

The joint resistance of two resistances in parallel is *the product of the two divided by their sum.*

Q. 3. Two resistances of 5 ohms and 20 ohms are in parallel. What is their combined resistance?

$$R = \frac{\text{product}}{\text{sum}} = \frac{5 \times 20}{5+20} = \frac{100}{25} = 4 \text{ ohms}$$

Working by the first method we have:

$$\text{Conductivity} = \frac{1}{5} + \frac{1}{20} = \frac{5}{20}$$

$$\text{Resistance} = \frac{20}{5} = 4 \text{ ohms.}$$

LESSON 19.

OHM'S LAW.

We have now stated what an ampere of current and an ohm of resistance are. The unit of pressure is the result of these two, for a volt is the pressure necessary to send one ampere of current through one ohm of resistance.

Knowing these three units of measurement and the law of flow of current we can solve many electrical problems.

Law of the Flow of Current.

With a given circuit the greater the pressure the greater the current, or if the pressure (voltage) remains the same, the less the resistance the more current flows.

Hence *Current* equals *Pressure* divided by *Resistance,*

$$\text{or Amperes} = \frac{\text{volts}}{\text{ohms}}$$

This is the regular form of Ohms Law and means:

The current in amperes in any conductor is equal to the difference in pressure between the ends of the conductor, in volts; divided by the resistance between the ends, expressed in ohms.

Expressed as a formula, Ohms Law is

$$C=\frac{E^*}{R} \text{ or } C=\frac{V}{R} \text{ or } C=\frac{PD}{R}$$

By E we mean the E. M. F., or electromotive force, that is the total pressure in the circuit measured in volts.

By V we mean the pressure (in volts) in the part of the circuit we are considering.

By P. D. we mean the Pressure Difference or difference in pressure (in volts) between the ends of the part of the circuit we are considering.

It is evident that V and PD are the same, while E is the sum of all the V's in the circuit.

The form V=CR means:

(1) The voltage required to maintain a current flow of C amperes through R ohms is given by the product of C and R.

(2) The drop of pressure or voltage lost in any conductor is equal to the product of the current C and resistance R.

In fact, the loss in pressure which always occurs when transmitting current is often called the CR loss. The "drop" is the usual term.

The form $R=\frac{E}{C}$ is used to find what resistance must be used in connection with a pressure E to limit the current to C amperes.

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*Electrical magazines and many text books use I for current, reserving C for capacity. It will soon be generally adopted by every one; but for a student C is more convenient and expressive.

Problem 1. An incandescent lamp having a resistance when hot of 240 ohms is connected to mains having 120 volts pressure between them. How much current does the lamp draw?

$$C=\frac{V}{R}=\frac{120}{240}=\frac{1}{2}\text{ ampere.}$$

Problem 2. What pressure will be required to force 7 amperes through an arc lamp whose resistance hot is 7 ohms?

$$V=CR=7\times7=49\text{ volts.}$$

Problem 3. What drop will there be in transmitting 2000 amperes to a locomotive 2 miles from power house, with a circuit whose resistance is 1/20 of an ohm per mile?

$$2\text{ miles}=2/20=1/10\text{ ohms.}$$

$$\text{Drop}=V=CR=2000\times1/10=200\text{ volts.}$$

Problem 4. In a car heater enough heat is generated when 10 amperes are flowing. Five of them are to be placed in series in a car. Voltage between third rail and track 500. What must be the resistance of the heater when hot?

$$500\text{ volts}\div5\text{ heaters}=100\text{ volts per heater.}$$

$$R=\frac{V}{C}=\frac{100}{10}=10\text{ ohms.}$$

Problem 5. In Fig. 146 let the dynamo of 0.01 ohms resistance be producing 100 volts as measured on the volt meter V. This is not the E. M. F. of the dynamo, because there is some drop in the dynamo. The 100

volts is the V. or P. D. at the ends of the external circuit.

This external circuit contains resistances as follows: A in series 2 ohms. C and E together in parallel, yet in series as a group with A. C is 100 ohms, E is 300 ohms. B is 3 ohms in series with A and the parallel group.

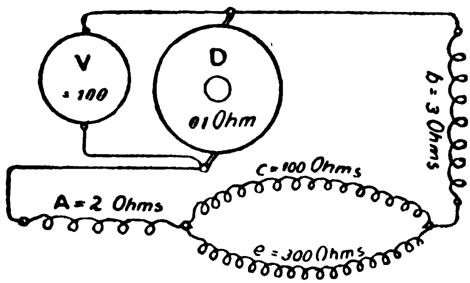

Fig. 146. Dynamo in a Series—Parallel Circuit.

What current flows through the dynamo?

The same current as through A or B for the circuit is a series one. The resistance of external circuit is as follows:

$$A = \qquad 2 \text{ ohms}$$

$$C+E \text{ jointly} = \frac{\text{product}}{\text{sum}} = \frac{30000}{400} = 75 \text{ ohms}$$

$$B = \qquad 3 \text{ ohms}$$

$$\text{Total} = 80 \text{ ohms}$$

A circuit of 80 ohms has 100 volts pressure at its ends, therefore,

$$C = \frac{V}{R} = \frac{100}{80} = 1.25 \text{ ampere flows.}$$

The drop in the dynamo must be

$$V = CR = 1.25 \times 0.01 = 0.0125 \text{ volts.}$$

A trifling amount, it is true, but should the dynamo deliver 1000 amperes the drop becomes 10 volts, which is large enough to be considered. If the voltmeter were placed around A what would it read? It would read the drop in A.

$$CR = 1.25 \times 2 = 2.5 \text{ volts.}$$

Grouping Cells or Dynamos.

A cell or dynamo is a source of E. M. F. and is in addition a source of resistance.

When we wish a higher voltage than one cell on machine will give, we connect several in series. This increases the voltage and resistance and the result depends on the resistances of the external and internal circuit. The part of circuit in the cells or dynamos is the internal circuit.

***Problem* 1.** Six blue stone cells, each 1 volt E. M. F. and 3 ohms resistance, are in series on a 100 ohm external circuit. Add 6 more in series. Will the current be doubled? Ri and Re are abbreviations for internal and external resistances.

Cell Ri= 3 ohms	
6 cells Ri= 18 ohms	E M F=1 volt
Re=100 ohms	E M F=6 volts
R=118 ohms	

$$C = \frac{E}{R} = \frac{6}{118} = 0.05 \text{ (nearly) amperes.}$$

Add 6 more.

$$\begin{array}{ll} Ri = 36 \text{ ohms} & E\,M\,F = 12 \text{ volts} \\ Re = 100 \text{ ohms} & \\ \hline \quad 136 \text{ ohms} & \end{array}$$

$C = 12/136 = 0.09$ (nearly) amperes.

Answer: The current is almost doubled.

Problem 2. The same cells as in Problem 1 are connected to external circuit of 1 ohm and 6 more cells are added in series. Is the current doubled?

$$\begin{array}{ll} 6 \text{ cells } Ri = 18 \text{ ohms} & EMF = 6 \text{ volts.} \\ Re = 1 & \\ \hline R = 19 & \end{array}$$

$$C = \frac{E}{R} = \frac{6}{19} = 0.32 \text{ (nearly) amperes.}$$

Adding 6 in series

$$\begin{array}{ll} Ri = 36 \text{ ohms} & EMF = 12 \text{ volts} \\ Re = 1 \text{ ohm} & \\ \hline R = 37 \text{ ohms} & \end{array}$$

$$C = \frac{E}{R} = \frac{12}{37} = 0.32 + \text{amperes.}$$

Answer. No. Practically no increase of current.

Moral: With high external resistance add more E. M. F. in series to increase current (the added resistance does no harm). With low external resistance add nothing in series unless it has a very low internal resistance.

Suppose in Problem 2 we had added 3 storage batteries at 2 volts and 0.33 ohms each.

Old Ri=18	Old EMF=6
New Ri= 0.99	New EMF=6
Re= 1.	
R=20 ohms	E=12 volts

$$C=\frac{E}{R}=\frac{12}{20}=0.6 \text{ amperes.}$$

Which is practically double the previous current.

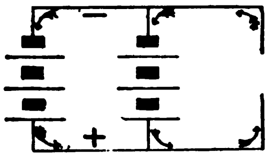

Fig. 147. Batteries in Parallel.

In Problem 2 had there been nothing available except 6 more blue stone cells they should have been put in parallel with the others, similar to Fig. 147.

Each set of 6 cells has Ri=18 but joint resistance of two groups is 9 ohms.

Ri= 9 ohms
Re= 1 ohm

R=10 ohms

The E. M. F. of each set of 6 cells is 6 volts and

the E. M. F. of the two groups not adding together makes E. M. F. of group, 6 volts as before.

$$C=\frac{E}{R}=\frac{6}{10}=0.6 \text{ amperes,}$$

which is practically double the previous current. Hence, when external resistance is low, lower your internal resistance by adding more cells in parallel.

There is a silly rule:

The best arrangement of cells is when the internal and external resistances are equal.

This is an arrangement to force the battery to deliver the greatest possible current. The efficiency will be 50% because since Ri and Re are equal the drop in each is the same, hence half the pressure is doing useless work and half useful work.

For economy have internal resistance low as compared with external resistance.

When a battery is at work on a high resistance line, add cells in series to increase current. When external resistance is low always add cells in parallel.

These rules do not apply to most dynamos because their internal resistance is very low.

With dynamos to get more voltage place extra machines in series. You will then get more current also.

To get more current at same voltage place extra machines in parallel with the first one.

LESSON 20.

METERS.

Galvanometers.

We have already seen in Lesson 12 that a current passing near a magnetic needle deflects it; also that a current passing first over a magnetic needle and then back under it in opposite direction deflects the needle further.

By a few simple tests you can convince yourself that increasing the current would increase the deflection.

An instrument consisting of a coil of wire carrying the current to be tested, and a magnet; the two being so arranged that one can be deflected, is called a galvanometer.

There are two types, the Thompson and the D'Arsonval.

The Thompson type has the coil of wire stationary and the light magnetic needle suspended by a silk thread. These can be made more sensitive than the other type, but are not portable and external fields have a great influence on them, causing them to give false indications. This is prevented by thick soft iron cases, much too heavy to be carried around.

The silk suspension makes the needle sensitive to vibration.

It is a fine laboratory instrument and with modified

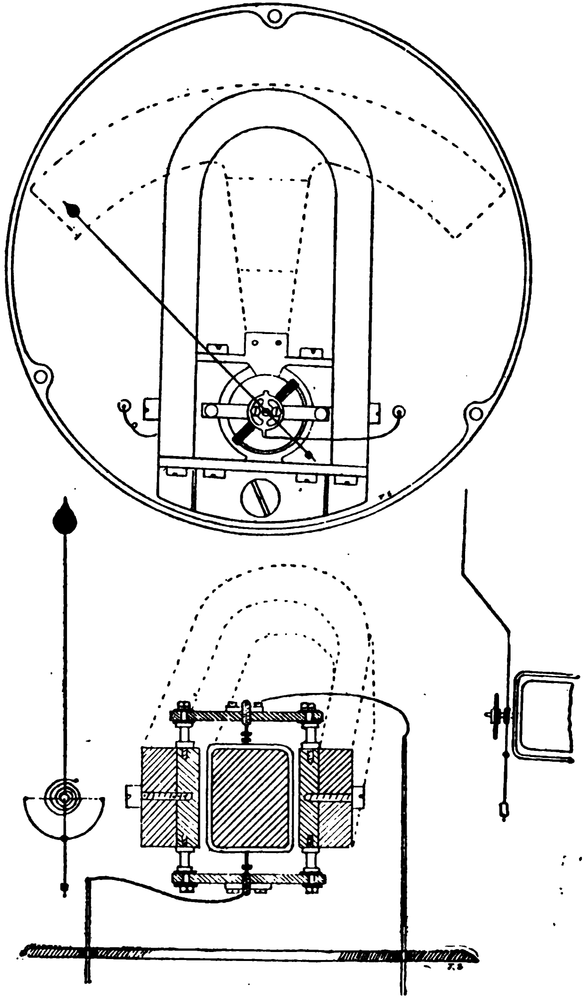

Fig. 148. Interior of Weston Instrument.

by the opposite effect on the other. The coil normally lies at 45° to the line joining the poles of the magnet, and consequently the magnetic field created by a current in the coil will be displaced relatively to the field of the horseshoe magnet as shown in Fig. 149, and the lines twist the coil through a certain angle against the action of the spiral springs, the angular movement of the coil depending on the strength of the current in the coil and the strength of the field in which it is placed.

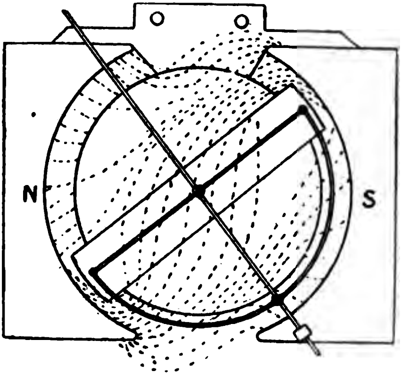

Fig. 149. Diagram of Magnets, Flux, Coil and Inner Core of Weston Instrument.

To the coil is attached a pointer of aluminum, the whole being balanced so that the instrument can be read in any position, and the pointer and scale are bent up so as to come near the front of the case.

A perspective view of movement is shown in Fig. 150.

In this instrument the whole current does not go through the coil, but only a small fraction of it. The

main part of the current crosses from one terminal to the other by a broad strip of metal under the base of the instrument, while the coil is placed as a shunt across the terminals, or as a conductor in parallel with the metal strip (Fig. 151), and consequently the ratio of

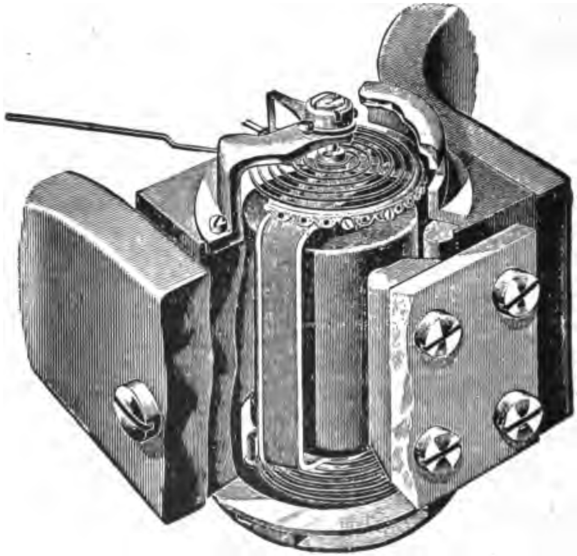

Fig. 150. View of Movement of Weston Instruments.

the currents in the strip and in the coil will be inversely proportional to their resistances. Now with a given strength magnetic field due to the magnet, and a given elasticity of the spiral springs, it will require a certain number of ampere turns in the coil to produce the full deflection on the scale. This can be secured by adjust-

ing the resistance of the strip connecting the terminals so that the same movement will do for any instrument. Thus, suppose the instrument were required to read to a maximum of 10 amperes, and we required 1 ampere in

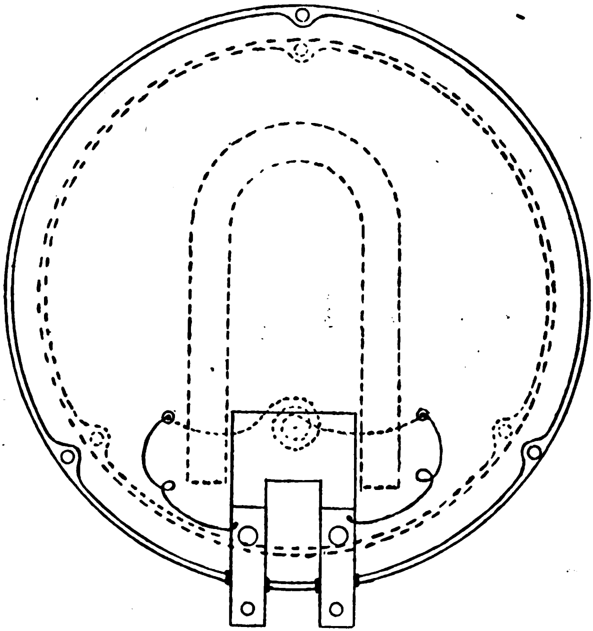

Fig. 151. Magnet and Shunt of Weston Ammeter.

the coil to give the maximum deflection,* then the resistance of the coil must be 9 times that of the strip, so that the current will divide at the terminals, 9/10

*It actually takes 1/100 amperes.

going through the metal strip and 1/10 through the coil. If the instrument is required to read to a maximum of 100 amperes, then the metal strip must have 99 times less resistance than the coil, and the current will then

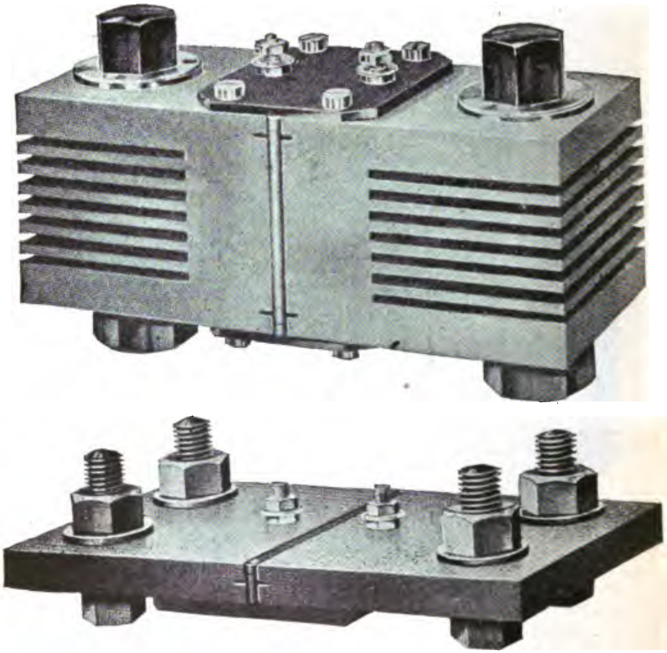

Fig. 152. External Shunts for Ammeters. 1000 and 5000 Ampere Sizes.

divide at the terminals, 99/100 going through the strip and 1/100 going through the coil, which will give a reading to the full range of the scale as before. By the arrangement of the pole pieces and wrought iron cylinder the field due to the permanent magnet is practically uniform over the range of movement of the coil, and so

the scale readings are the same size throughout. Should the permanent magnet vary in strength, the instrument would not read correctly, but the magnets are so treated that the falling off in strength over a number of years is inappreciable.

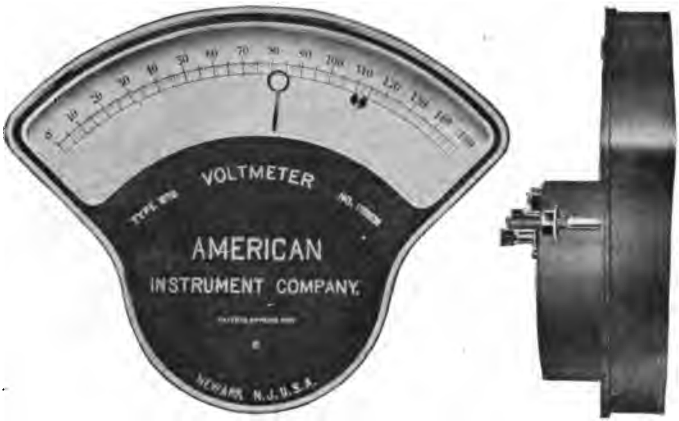

Fig. 153. Switch Board Instrument.

The strip or shunt for portable instruments is always inside the case, while for switchboard instruments the shunt is too large (Fig. 152) and is placed separately on the back of the board. Leads* are run along the board to the meter terminals which project through holes in the board from the meter which is in front.

Such a switchboard instrument is shown in Fig. 153 and Fig. 154.

A voltmeter is made by removing the metal strip or

*Technical name for wires.

shunt connecting the terminals and placing a resistance coil in series with the moving coil.

As it takes 1/100 amperes to swing the pointer over full scale for every volt the instrument reads, it must have 100 ohms in the resistance coil.

A 500 volt instrument will have 500,000 ohms resistance, and hence 1/100 amperes will flow through the moving coil.

Fig. 154. Switch Board Ammeter.

The moving coil is wound on a copper or aluminum frame, which when it swings has current induced in it by the magnets and stops vibrating very quickly; in fact you cannot detect any vibration. The needle seems to move to a certain spot and stop dead. This is called a "dead beat" needle; a more scientific name is "aperiodic."

Some instruments have electro-magnets instead of permanent magnets. The Thomson Astatic instruments are

of this type. Two of these instruments are shown in Figs. 154 and 155. This latter has a scale or dial of opal glass with an electric light behind it. This makes the instrument easily read from a distance or at night. These are called "illuminated dial instruments."

Fig. 155. Illuminated Dial Instrument.

The instrument of Fig. 153 has an extra hand ending in a ring. This can be set at the voltage you wish to maintain. The most hasty glance will then tell you whether your voltage is too high or too low.

In order to save space on switchboards some instruments are made thin and broad and are set horizontally or vertically.

Fig. 156 shows the exterior and interior of a Thomson Edgewise Ammeter.

The Thomson Inclined Coil instruments as shown in Fig. 157 are portable instruments used for alternating

current only. In an emergency they can be used to measure direct current by reading, reversing current, reading again and averaging results.

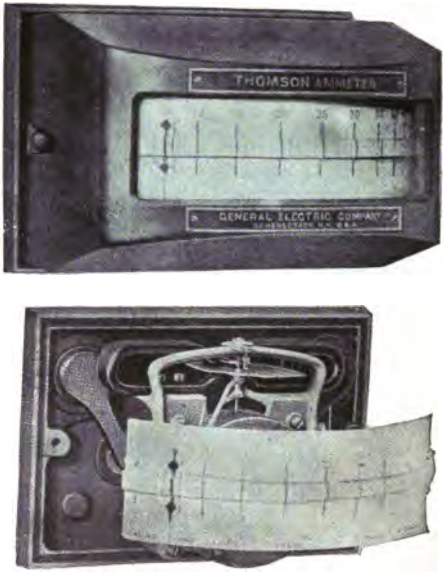

Fig. 156. Thomson Horizontal Ammeter.

The action of the magnetism of the inclined coil is twist the inclined sheet iron vane "a" around to the dotted line position.

The Weston instruments described are for direct current only. The company makes an alternating current voltmeter but no ammeter. Thomson Astatic instruments

are for direct current. The Thomson Inclined Coil in portable, or edgewise switchboard form is for alternating current.

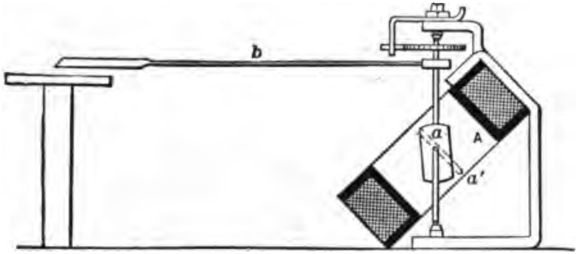

Fig. 157. Thomson Inclined Coil Instrument.

Wattmeters.

By combining two coils, one movable, the other stationary, one attached as a voltmeter with series resistance, the other attached as an ammeter, with a shunt, we get an instrument whose needle indicates power or watts. These are called indicating wattmeters.

The recording wattmeter records watt-hours. A watt-hour is one watt of power used for an hour, or any combination like one-quarter of a watt for four hours, etc.

The Thomson Recording Watt-Hour Meter is used for direct or alternating current. It is shown with dust-proof case removed in Fig. 158. The connections made to it are shown in Fig. 159. By "light" in the figure must be understood any load at all.

The meter consists of an electric motor whose armature A is supplied with current from the mains through a high resistance P in the back of the instrument and a small field coil on right-hand side.

This armature is in shunt across the circuit, hence its current is proportional to the voltage.

The main current passes through the field F, hence the strength of the field is proportional to the current.

The speed of the motor is therefore proportional to both current and voltage, that is to the power or watts.

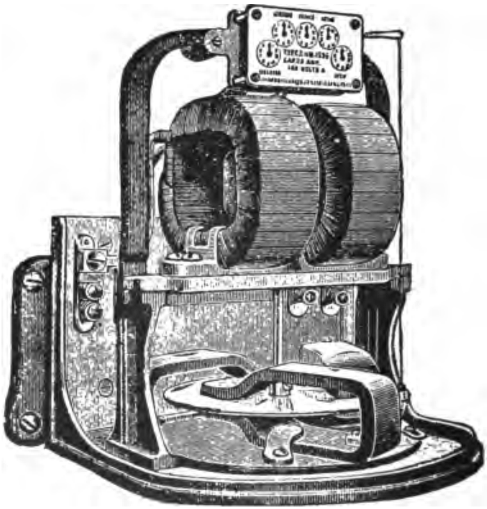

Fig. 158. Thomson Recording Watt-hour Meter.

The armature shaft goes on past the commutator to a cyclometer with dials like a gas meter. The revolutions are here recorded as watt-hours.

The auxiliary field is just strong enough to nearly overcome the friction in the bearings and cyclometer, so that the smallest current through the mains will produce rotation.

At the bottom of the armature shaft is an aluminum disk revolving between the poles of permanent magnets. This device prevents the meter from running at too great a speed and gives an adjustment for accuracy.

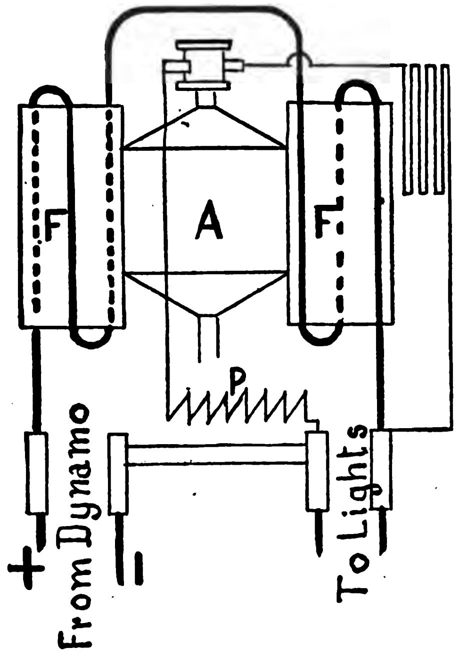

Fig. 159. Diagram of Connections. Thomson Recording Watt-hour Meter.

The further out the magnets are swung the faster is the motion of the metal passing between their poles and the greater a retarding effect they produce.

A meter running too slow from age or dirty bearings could be brought up to proper speed by swinging the magnets in a little.

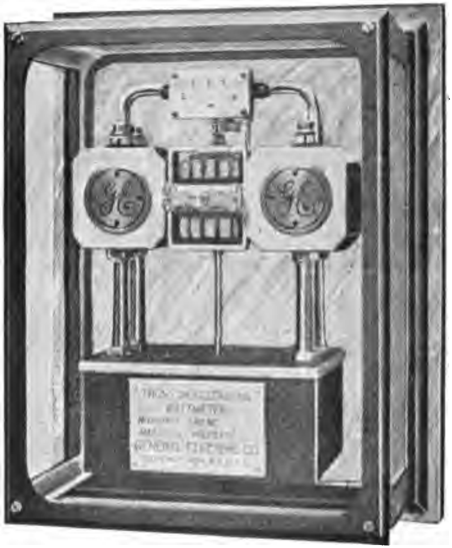

Fig. 160. Large Capacity Thomson Recording Watt-hour Meter.

For large currents the appearance of the meter is quite different, as is shown in Fig. 160. The retarding device is enclosed in a case and the whole instrument enclosed in a dust-proof glass case.

LESSON 21.

Electrical Work, Power and Efficiency.

FORCE.—Force is defined as that which produces motion, or a change of motion; thus force must always be applied to any body to cause it to move. To increase, decrease, or stop this motion, that is to change it, force must again be applied. For example, to start a loaded wheel-barrow force must be applied, either by pushing or pulling it, but when it is set in motion less force will be required to keep it in motion; to cause a change in motion, that is to increase or decrease the speed, extra force must be applied. Force does not always produce motion, but only tends to produce it, as when a man tries to push a laden freight car he applies all his muscular force, but no motion results.

DIFFERENT KINDS OF FORCE.—There is the force of gravitation, which causes all bodies free to move to fall from a higher to a lower level. The force exerted by a man riding a bicycle or a horse drawing a carriage are examples of muscular force. An engine draws a train of cars by reason of the mechanical force applied, which is due to the expansion of the steam in the steam cylinder. A mixture of air and illuminating gas in a room is ignited and the explosion wrecks the room; the action is due to the chemical force exerted. The force which produces or tends to produce a flow of electricity is electromotive force. The rate at which a train moves

depends upon the force exerted by the engine, so also, the rate of flow of electricity depends upon the amount of electromotive force applied.

MASS AND WEIGHT.—The mass of a body is the quantity of matter in it; the weight of a body is due to the force of gravity acting upon this matter. Since the force of gravity diminishes as we ascend from the earth's surface, the attraction for a mass of matter will diminish, or it will weigh less on the top of a high mountain than at the sea level; the mass of matter, however, would be the same in each case. Weight is not, therefore, the same thing as mass, but we can conveniently measure a body by its weight.

WORK.—Work is done when force overcomes a resistance, or, work is force acting through space ($W=F\times S$).

$$\text{Work}=\text{Force}\times\text{Distance},$$

$$\text{or Work}=\text{Pounds}\times\text{Feet}=\text{Foot-pounds}.$$

Work is not always done when a force acts; for instance, a man pushes with all his force against a brick wall; he is exerting force, but doing no work because no motion results, nor is any resistance overcome. If a weight be lifted, work is done directly in proportion to the weight and to the distance through which it was moved. Thus, the work done in lifting 4 pounds to the height of 3 feet is equivalent to 12 foot-pounds of work. Exactly the same work is performed when two pounds are lifted 6 feet; or 6 pounds raised 2 feet; or 12 pounds raised 1 foot. Work does not always consist in raising weights; the steam engine does work by hauling a train, due to the expansive force of steam acting upon the piston; an explosion of powder in a cannon causes an iron

ball to traverse a certain distance. The magnetic action in a dynamo sets up a force which causes a current to flow through an electric motor and the motor drives a car weighing so many pounds a certain number of feet every minute, hence the total foot-pounds of work are performed electrically. The work in each case is measured in foot-pounds. Whether work be done mechanically, chemically, thermally,* or electrically, it can be expressed in foot-pounds. The total amount of work done is independent of time, that is, the same work may be performed in one hour or one year. When different amounts of work performed in different times are to be compared, then reference is made to the time, or rate of working, or the power.

POWER.—Power is the rate at which work is done, and is independent of the amount of work to be done.

$$\text{Power (rate of working)} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Foot-pounds}}{\text{Time}} =$$

$$\text{Foot-pounds per unit of time.}$$

For example, it requires four hours for a particular engine to draw a train from one station to another, while another engine may draw the same train the same distance in two hours. One engine is thus twice as powerful as the other, because it can do the same work in half the time. When the train has reached its destination it would have represented the same amount of work done, no matter whether it had traveled at one mile per minute or one mile per hour, leaving, of course, friction and air resistance out of account.

---

*By heat.

Power is estimated according to the amount of work done in a given period of time. As mechanical work is measured in foot-pounds, mechanical power would thus be so many foot-pounds per minute, or per second. The mechanical unit of power is the horse power.

One Mechanical Horse Power=33000 ft. lbs. per Minute

$$\text{or } \frac{33000}{60} = 550 \text{ ft. lbs. per Second.}$$

If a body weighing 33000 pounds be raised one foot every minute then we have a rate of working equal to one horse power; or if 16500 pounds be raised two feet per minute, the rate of working is the same, one horse power. If the work were continued at the same rate for one hour, we would have a larger unit of work, or the horse-power-hour. When we say that an engine is developing 40 horse power we mean that it is performing $550 \times 40 = 22000$ foot-pounds of work every second.

DIFFERENCE BETWEEN ENERGY, FORCE, WORK AND POWER.—It is important that the student should thoroughly understand the meaning of the above terms. *Energy* is the capacity to do work. *Force* is one of the factors of work and has to be exerted through a distance to do work, the work being reckoned as the product of the force and the distance through which it has been applied. *Work* is done when energy is expended or when force overcomes a resistance. *Power* is the rate of working.

ELECTRICAL WORK.—Work is force acting through space, or energy expended, therefore, resistance is overcome when work is performed. Force may exist without work being performed, as when you push against

a table and do not move it, no work is done, yet the force exists. An electrical force exists between the two terminals of a battery, tending to send a current of electricity from one to the other through the air. The force is not sufficient to overcome the resistance of the air, therefore no current flows and the battery is not doing any work; the same is true with a dynamo when running on open circuit. When a wire is connected across the battery terminals, the force overcomes the resistance of the wire and electricity is moved along, around or through the wire, which becomes heated. The electrical work, or energy expended, in this case, is represented by the amount of heat generated. With a small lamp connected to the battery, the work is represented by the heat and light given by the lamp as well as the heat given to the remainder of the circuit. The total work performed is the product of the force, the current, and the time that the current is maintained or

$$\text{Electrical Work} = \text{Volts} \times \text{Amperes} \times \text{Time}.$$

But the engineer is not interested much in work—the element of time is of great importance to him, so he always figures power used.

ELECTRICAL POWER.—Power is the rate at which energy is expended, and is independent of the total work to be accomplished. The rate of working, or the power, is found by dividing the total work by the time required to perform it.

$$\text{Electrical Power} = \frac{\text{Electrical Work}}{\text{Time.}}$$

The unit of electrical power is a unit of work performed in a unit of time, and is called a *Watt*.

$$\text{Power} = \text{Volts} \times \text{Amperes} = EC.$$

Problem 1. A current of 2000 amperes flows at a pressure of 600 volts. What power is used?

$$\text{Watts} = EC = 600 \times 2000 = 1200000.$$

To avoid the use of large numbers the Kilowatt is used. It is 1000 watts.

The answer to Problem 1 is therefore 1200 K. W. (Kilowatts abbreviated K. W.).

Problem 2. How many K. W. will an alternator producing 11000 volts and 272 amperes give?

$$\begin{aligned} W = EC &= 11000 \times 272 \\ &= 2992000 \text{ watts} \\ &= 3000 \text{ K. W. (nearly)}. \end{aligned}$$

A watt is a small unit, for it takes 746 watts of electrical power to exert the same power as one horse power of steam power.

Hence 746 watts = 1 horse power (H. P.)
and ¾ K. W. = 1 H. P. (approx.)
1 K. W. = 1⅓ H. P. (approx.)

A rough rule for figuring is:

To change from K. W. to H. P. add on ⅓ of the number, from H. P. to K. W., subtract ¼ of itself from the number.

A very convenient formula for power is obtained in this way:

$$W = EC, \text{ but } C = \frac{E}{R}$$

$$\text{hence } E = CR, \text{ so } W = CR \times C = C^2R.$$

This means the watts power used up in any resistance is found by the formula $W=C^2R$. The square of the current multiplied by the resistance.

This is all wasted power and is often referred to as the "C square R loss."

When a current goes through a motor it produces some mechanical power, but when flowing through a wire it produces nothing but magnetism and heat. This is often referred to by saying a current produces C^2R heat, meaning that the current produces C^2R watts which turn to heat.

EFFICIENCY.

When we bring 223.8 K. W. of energy to a motor and turn out at its pulley 240 H. P., it is because some of the energy has been lost in the transformation from electrical to mechanical power.

223.8 K. W.=223800 watts.

$223800 \div 746 = 300$ H. P.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Intake}}$$

Both being expressed in same units,

$$\text{efficiency} = \frac{300}{240} = 0.8.$$

Efficiencies are usually multiplied by 100 and then called per cent. Efficiency of 0.8 would be called 80% efficiency.

CIRCUIT BREAKERS.

In its simplest form a circuit breaker is merely a switch so designed as to be capable of frequently opening the circuit carrying its full current without any damage to itself.

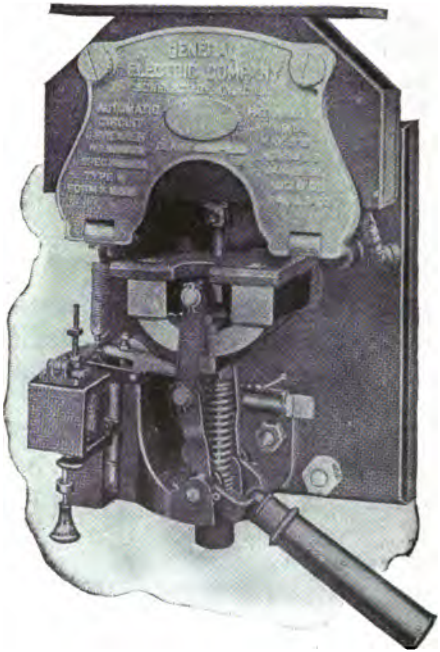

Fig. 161. Automatic Circuit Breaker with Low Voltage Release, Tell-tale Switch and Magnetic Blow-out.

With the large currents handled in railroad work it has become necessary to define a switch as "a piece of apparatus to close circuits."

Apparatus to open circuits* are now called circuit breakers, trip switches, oil switches or some other special name.

In order to have a good contact for carrying current where breaker is closed, this contact is of copper.

As shown in Fig. 161, the contact is composed of two large copper blocks against which press the ends of a curved copper brush. This brush is made of numerous thin sheets of copper, pressed together so as to form an almost solid block of metal. They are held together tightly in the middle, and the ends left free.

When the brush is pressed upwards against the blocks it makes a peculiar scratching or rubbing contact in which each separate leaf of the brush makes its own contact, and holds it with a firm pressure owing to the springiness of the copper.

The scratching or rubbing contact ensures the removal of all dirt or oxidized copper from the block and the individual action of each leaf makes a good contact, utilizing the total surface of the brush.

While such a contact is an excellent carrier of current, it is the worst possible breaker of a current, for the separate leaves would melt on the edges and fuse together.

The breaker is arranged so that a second contact of a carbon plug in a carbon socket always closes before and opens after the main copper contacts.

In Fig. 161 this secondary carbon contact is on the

*It will be understood that after breaking a current by a circuit breaker the mere opening of a knife switch cannot be called opening a circuit, because after the breaker opens there is no electrical circuit.

end of the rod which passes up into the hollow formed by the nameplate.

In Fig. 162 the carbon plug is K and the sides of the socket are marked G. The main contact blocks are the squares and the copper brush is marked H.

The toggle which closes and opens the breaker is marked F.

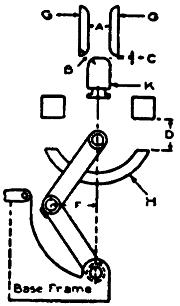

Fig. 162. Diagram of Fig. 161.

In Figs. 163 and 164 the carbon contacts are seen at the top in the shape of carbon blocks. In Fig. 163 the main contact is plainly shown below, while in Fig. 164 the main contact is concealed by a metal housing.

The mechanical connection between the main (copper) contacts and the secondary (carbon) contacts has enough lost motion that the main contact is well opened before the secondary opens.

What has been described constitutes a circuit breaker, but a circuit breaker is always an automatic device. An oil switch may or may not operate automatically, but when we say circuit breaker we always mean an automatic one.

The circuit breaker is set by hand against a spring and held shut, closed, or set (the three words meaning the same thing) by a latch or hooked catch. There is a rod one end of which is arranged to unfasten or trip

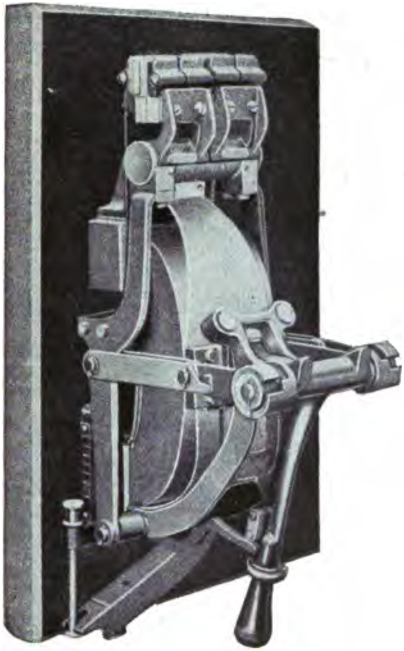

Fig. 163. Large Capacity Breaker. Carbon Break Type 2000 to 10000 Amperes.

the catch, the other end is fastened to an iron armature or core.

All the current in the particular circuit which the breaker is in passes through a solenoid which exerts an attraction on the core or armature.

Suppose the normal current on the line to be 700 amperes, then the circuit breaker would have contacts of sufficient area and a solenoid of such a size that 700

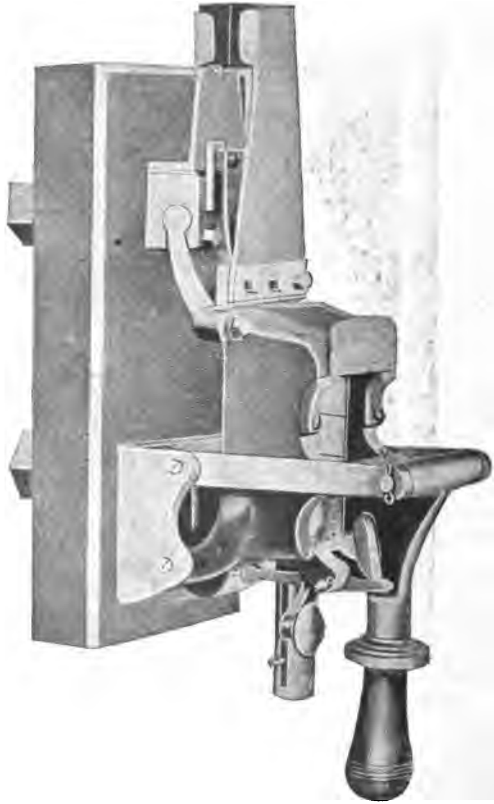

Fig. 164. Carbon Break Circuit Breaker, 150 to 800 Ampere Capacity.

amperes could pass through the breaker 24 hours a day without overheating any part.

The weight of rod and core of armature would be sufficient so that the lifting power of the solenoid was not great enough to lift them, but that 1000 amperes through the solenoid will lift the rod and release the catch. The spring then opens the breaker. When a circuit is to be opened the attendants push up the rod and thus open the breaker.

Fig. 165. Magnetic Blow-out Breaker. Small Capacity.

When this is done it is called tripping the breaker, when the breaker is tripped by the action of the current it is customary to say the breaker has "blown."

Whether a breaker is tripped or blown, it makes a noise like a pistol shot. The larger the current blown, the greater the noise.

The tripping solenoid is shown plainly in Fig. 165.

If large currents are handled by the breaker a solenoid of one-half a turn may create enough power to trip the breaker.

In Figs. 163 and 164 this is the case, and the tripping device is not in evidence.

If the rod and its attachments were heavier it might take 1200 amperes to trip the breaker; if the core or armature were moved nearer or further from the solenoid, a smaller or larger current would trip the breaker; if a more or less strong spring were attached the current required to blow the breaker would vary with the tension of the spring.

These devices are used to set the current at which the breaker will operate.

Breakers are made to have a capacity for certain currents continuously passing through them without over heating. This is called their Continuous Capacity.

The carbon contacts are then designed to break a current of from 50% to 100% in excess of this current for several hundred times without needing renewal of parts. This is called the maximum capacity.

Sometimes the maximum capacity is two or three times the continuous capacity. Such breakers must be very heavily and strongly built, and are much higher in price.

The lowest current at which the breaker can be set to operate is called its minimum calibration.

In Fig. 163 at the left side is a rod screwed in an arm. The lower end of this rod has a flange which holds an armature from falling down, but does not prevent its rising.

The upper end of the rod moves past a scale marked in amperes. Turning this rod till its head is opposite

a certain number draws the armature into such a position that the indicated number of amperes will pull the armature up and release the catch or trigger, which can be plainly seen holding the arm which operates the toggles in place.

It is evident that the scale reads from the top down, for then setting screw at smallest number brings the armature nearest the solenoid. Fig. 165 shows the armature above the solenoid with a spring to change the pull required to draw it down and release the trigger.

In this breaker the main contacts are between the handle and the solenoid, while the secondary contacts are up top behind the name plate.

In Fig. 166 is shown a breaker with a core in the solenoid.

The main current circulates around the solenoidal coil "B" and tends to draw into the solenoid the movable plunger "C." The initial position of this plunger in the solenoid is determined by the adjusting screw "M." When the current is sufficient to overcome the weight of the plunger it is drawn into the coil with constantly increasing velocity, due to intensified magnetic action, as the polar distances or air space is decreased. When nearing the upward limit of its travel, having acquired a high momentum, it impinges upon the trigger "N" through the medium of the push pin "E." The immediate result of this is the release of the switch arm by the displacement of the retaining catch "F." The upper projection "H" of the trigger "N" is thrust against the striker plate "K," thereby utilizing the energy of the current to start the movement of the switch arm. This movement is intensified and sustained beyond the point of final rupture between the

switch contacts by the thrust of the spring "O," which is released from compression by the initial action of the trigger. Thus the contact arm is thrown away from the contact terminal, and the circuit is opened.

As the screw "M" is turned up and locked by "T" it prevents the core "C" from falling away from the solenoid. The higher "C" the lower the current at which breaker blows.

The fact that the current is broken between the carbon blocks tends to suppress the arc formed, and in the breakers shown in Figs. 163, 164, and 166 this is alone relied on to kill the arc.

It must be remembered that although these breakers have two contact blocks at the main copper contact, yet only one wire of the circuit is attached to the breaker. The current enters at one block, goes over the copper brush to the other and out to the line. The carbon contacts are a shunt. Circuit breakers are adapted to different voltages by the excellence of the insulation and by the length of the openings between contact pieces.

The breakers shown are all suitable for D C and A C circuits of 100 to 800 volts.

The breakers shown in Figs. 161 and 165 have a magnetic blowout; that is, a solenoid is situated at the carbon contact, which actually blows the arc out the same as in the Thomson lightning arrester.

The breaker in Fig. 161 has two attachments which are of great service. These are the Low Voltage Release and the Tell Tale.

The way these act is best explained in connection with Fig. 167.

The Low Voltage Release is a coil of low resistance

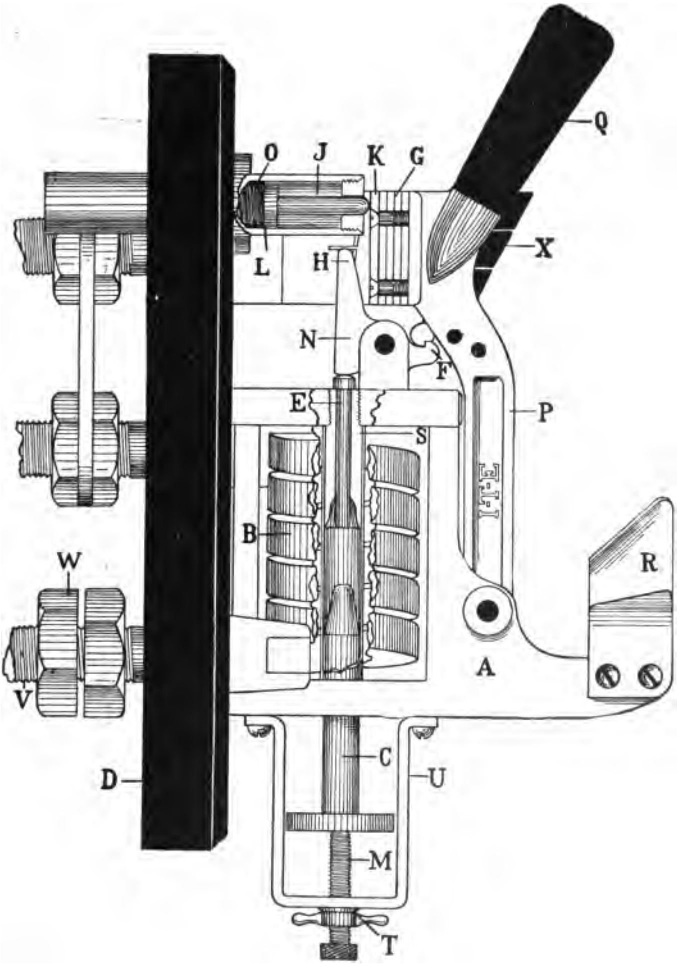

Fig. 166. Cross Section of Circuit Breaker.

holding by its armature the trigger of the breaker. A resistance is placed in series with this coil and both together are placed as a shunt across the line. In the

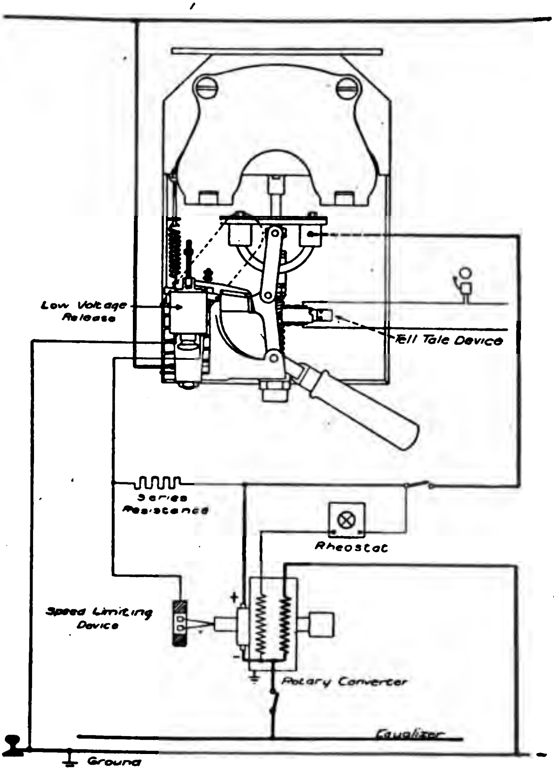

Fig. 167. Electrical Connections of Fig. 161.

diagram one side of the release coil is connected to ground, which is negative, and the other side through the series resistance to the positive brush of rotary converter.

As long as the voltage is normal this coil is a strong enough magnet to hold the breaker trigger set, although at any time the main solenoid can release the trigger independently of the low voltage coil.

If the voltage falls to half the normal pressure the coil becomes such a weak magnet that the trigger is released and breaker opens.

Wires are often run from the terminals of the low voltage coil to push button in different parts of the station.

Pushing the button then forms a short circuit across the low voltage coil and robs it of its current. It ceases to be a magnet and the trigger is released. The breaker can thus be opened from several distant points.

To prevent rotary converters from racing at great speed, when power on A C side is suddenly thrown off, there is a speed limit device on the rotary which consists of a ring in which a fly-ball governor rotates. The ring is connected to one side of the low voltage coil and the fly-balls through the negative wiring, to the other side. When the rotary goes too fast the fly-balls open out and touch the ring, completing a short circuit across the low voltage coil and thereby releasing the trigger.

The Tell Tale is merely a mechanically operated switch, which the opening of the breaker closes. The tell tale may close the circuit of an electric bell and call the attendant's attention.

It usually rings a bell and lights a lamp. It may even trip a second breaker, if it is desired to always have the two "go out"* at the same time.

For higher voltages, 6600 volts and upwards, break-

*Another expression for "blowing."

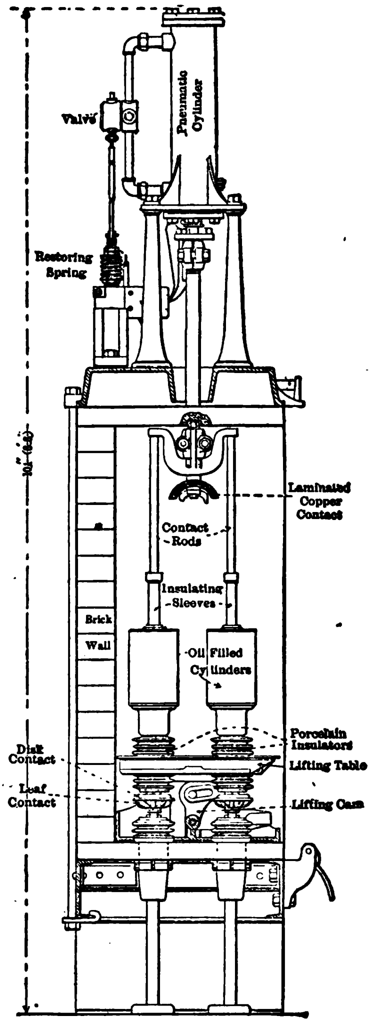

Fig. 168. Oil Circuit Breaker.

ers of type shown in Fig. 168 are used. A magnet when current is too large operates the valve which admits air to the cylinder. The cylinder piston through a wooden rod operates the main contact first and then the secondary contacts which are enclosed in oil filled cylinders.

LESSON 22.

Direct and Alternating Current.

We have seen that when direct current, as it is called, passes through an electro-plating bath, there is a transfer of chemicals in both directions. The metals go from the anode to the cathode, i. e. from + to — negative wire. The non-metals such as sulphur, chlorine, etc., are transferred from the cathode to the anode.

It seems as if direct current flowed in both directions around the circuit, but since the metals are of the most importance to us we speak and often think of direct current as flowing only in one direction.

The test for direct current is that it will electro-plate.

Ohms Law in its simple forms as mentioned in Lesson 19, applies absolutely to direct current.

It is a fact that for the first fraction of a second after a switch is closed the current is growing to the value it ought to have as given by Ohms law.

This growth is very rapid when the circuit contains no coils or magnets. These retard the rise of the current.

The current in the field circuit of a dynamo may take 3 seconds to attain its full value, but once there its value is given by Ohms Law.

Alternating Current.

An alternating current will not electro-plate, for the metal-plating part of the current reverses direction many times a second.

An alternating current will not deflect a magnetic needle because the deflecting impulse reverses its direction continually.

Alternating current can excite a magnet causing a core to be sucked into a solenoid or an armature to be attracted, because induced magnetism in core changes with the polarity of magnet itself.

Alternating current measuring instruments do not contain magnetic needles, but are supplied with two coils. The magnetic action between these two coils is just as strong as if direct current were used, because the A. C. reversing in each coil at the same time keeps the relative polarities the same.

Other A. C. instruments like the Thomson Ammeter Fig. 157, exert a magnetic action on a vane. This vane is not itself a magnet.

Since A. C. does not electro-plate the original definition of an ampere is of no use here, but since the heating done by electricity is the same for equal quantities whether A. C. or D. C. we define thus:

An ampere of A. C. is that current which produces as much heat per second as one ampere of D. C.

For example: A car heater raises the temperature of the car from 60° Fah. to 70° in half an hour. The ammeter read 20 amperes D. C. If A. C. were supplied and raised the temperature from 70° to 80° in the next half hour we would say that 20 amperes A. C. were flowing.

Ohms Law applies to A. C. when written thus:

$$C = \frac{\text{Impedance}}{\text{Volts}}$$

The *impedance* is larger than the resistance of the circuit, it being the result of the resistance and the reactance.

Resistance is the opposition offered by a conductor to any or all current passing.

Reactance is the extra opposition offered by a conductor to a current which is changing in value. It depends on the rapidity of this change and on the number of coils of wire in the circuit. It is measured in ohms and is calculated by the formula:

$$\text{Reactance} = 6.28 \times f \times L$$

where f=frequency

L=coefficient of Self-induction.

The frequency, as explained before, is the number of times the current reverses per second. It runs from 25 in power and railroad work up to 133 in electric lighting. It is best determined by taking the speed of the alternator in the power house and counting the number of pairs of poles that alternator has.

Calculating the number of pairs of poles passed a second gives the frequency.

Problem: An alternator makes 75 revolutions per minute and has 40 poles; what is the frequency of the current delivered?

40 poles=20 pairs poles

75 r. p. m.=1.25 r. p. second

$20 \times 1.25 = 25$ pairs poles per second.

25=frequency.

Self Induction.

When the current changes strength in a long straight wire the resistance of the wire does not resist the change, for the resistance offers the same opposition to any or all currents; it is the magnetic field around the wire which causes the *reactance* of the wire.

Every current has its definite magnetic field in the air around the wire and when current is increased the magnetic field has to increase to its new value. When the current alternates the rapid dying away and regrowth of the magnetism consumes some of the power so that for the same E. M. F. the current is less when it is A. C. than when D. C.

The greater the frequency the greater is the reactance of the circuit because the more frequent the rise and fall of the magnetic field about the wire.

Perhaps it would be truer to facts to say that the rise and fall of the magnetism causes it to cut through the wire and produce an E. M. F. opposite to that produced by the alternator which reduces the net E. M. F. impressed on line.

When coils of wire are present this action is much stronger because the magnetism cuts the circuit oftener on each rise and fall.

The action of the coils is called Self-Induction and the number representing the action is called *henrys,* named after Henry, a noted electrician.

It is well to remember that the reactance of the circuit is caused by the frequency of the A. C. and the self-induction of the circuit.

Problem: Suppose a circuit of 0.12 henrys self-induction and 184 ohms resistance conducts A. C. at a frequency of 60. What will be the current flowing with 11000 volts

$$\begin{aligned} \text{Reactance} &= 6.28 \times f \times L \\ &= 6.28 \times 60 \times 0.12 \\ &= 45 \text{ ohms} \\ \text{Resistance} &= 84 \text{ ohms} \end{aligned}$$

Impedance=Square root of the sum of squares of resistance and reactance.

Resistance squared=7056 ohms
Reactance squared=2025
Sum of squares=9081
Square root=95.3
Impedance=95.3 ohms.

$$C = \frac{\text{Volts}}{\text{Impedance}} = \frac{11000}{95.3} = 115.4 \text{ amperes.}$$

Capacity.

The presence of condenser action or capacity in a A. C. circuit is a help because all circuits have some inductance (self-induction plus the effect of any circuits near the one in question), and the capacity tends to neutralize this, bringing the value of the impedance nearer to the resistance.

It is even possible to artificially make the capacity so great that the impedance is practically equal to the resistance.

Such a circuit would conduct A. C. or D. C. equally well.

Lagging, Leading Currents.

If a shunt is put in a circuit and an ammeter connected to it, while a voltmeter is connected to the same part of the circuit, if* readings could be taken of the values of current and voltage at any instant of time we would find that the highest value of voltage and current did not appear at the same time.

We would see that the value of the current as given by C=Volts÷Impedance, occurs a fraction of a second after the voltage causing the current has passed. We say the current lags behind the voltage. If we add more inductance to the circuit the current will lag more and more until it seems to the observer at an oscilligraph that the current can hardly belong to the voltage he is watching, because the largest current is flowing when the voltage is almost down to zero and positive current is flowing when the voltage has reversed and is negative.

If capacity is now connected to the circuit the current will move up to a position nearer where it naturally should be until with sufficient capacity it will follow exactly the changes in the voltage. That is the highest current and voltage will occur at exact instant.

Add more capacity and remove all inductance possible by taking out of circuit all coils or machinery containing coils, especially if they have iron cores.

The current will actually lead the voltage. That is, the highest current will flow a fraction of a second before the highest voltage occurs.

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*An instrument called an oscilligraph can make these instantaneous readings.

Power Factor, Wattless Current.

The power in this circuit while all these changes have been going on has varied greatly. When the current and voltage were together the power was the greatest, when the current either led or lagged the power was less. This is because the power is determined by multiplying the current and voltage which occur at the same time. It makes no difference whether that voltage belongs to that current or not. It is the product of the things which are happening at the same time which gives the power.

If an A. C. ammeter and voltmeter are put in circuit each instrument reads the average current or voltage irrespective of the time at which these currents or voltages occurred. Multiply these two readings and you get the power produced by the current and the voltage which belongs to it. If you should now place a wattmeter in the circuit it will measure the actual power, i. e. the average of current multiplied by the voltage which occurs at the same instant.

This wattmeter reading is the actual power. The ammeter reading multiplied by voltmeter reading gives the apparent power.

The decimal number by which the apparent power must be multiplied to get true power is called the Power Factor.

If a current of 250 amperes is flowing at a pressure of 1000 volts we have an apparent power of 250000 watt or 250 K. W. If the true power as read by the wattmeter is 200 K. W. the power factor must be 0.8 for $250 \times 0.8 = 200$.

$$\text{Power Factor} = \frac{\text{True power}}{\text{Apparent power}}$$

$$= \frac{\text{Wattmeter reading}}{\text{Volts} \times \text{amperes}}$$

By saying that the pressure measurement is correct we throw the blame on the current and say that all the current which flows, say 250 amperes at 1000 volts, is measured by the ammeter, while only the current which works or produces watts is taken into consideration by the wattmeter. According to this idea the wattmeter would only notice $250 \times 0.8 = 200$ amperes. The other 50 amperes are called the wattless or idle current.

It is customary to speak of A. C. waves. This is quite natural for the rise and fall of voltage and current in an A. C. circuit reminds one of the waves in a long string which is shaken to and fro at one end while being held fast at the other.

LESSON 23.

TRANSFORMING DIRECT OR ALTERNATING CURRENT.

Direct Current.

Perhaps one of the greatest objections to the use of direct current is the inability to change its voltage without the use of moving machinery.

There is but one way to transform D. C. and that is by a motor and generator.

This motor-generator set usually consists of a D. C. motor driven by current at the pressure of the incoming line. This motor drives a D. C. generator which furnishes current at the desired pressure.

By altering the strength of the field of the generator we regulate the outgoing pressure to suit the requirements.

The motor and generator are built on the same shaft and set on a long cast iron base, making them mechanically one machine.

When the incoming and outgoing voltages can have the same ratio to each other always, a cheaper form of machine can be used called a Dynamotor.

This is a D. C. motor running on the incoming voltages. On the same armature core is a separate winding connected to its own commutator at the other end of armature. The one set of field magnets serves for the motor winding and the generator or dynamo winding.

This inability to transform cheaply seems to be a great disadvantage, but as we so seldom want to do it the inability to do so does not bother us much.

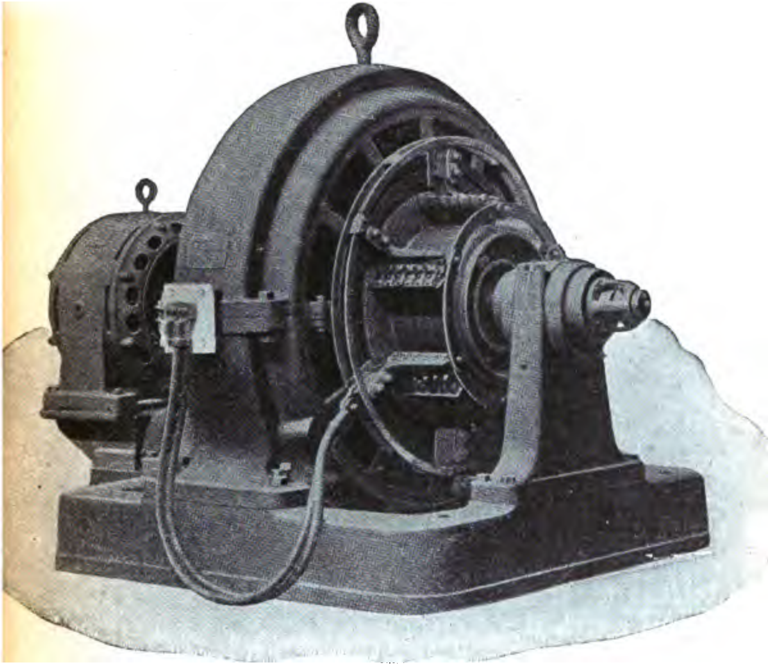

Fig. 169. 500 K. W. 3 Phase Rotary. 460 A. C. Volts to 660 D. C. Volts. Frequency 25. Commutator End.

In railroad work when we wish to charge storage batteries from 600 volts circuits we use a motor-generator.

Alternating to Direct Current.

Many D. C. traction systems transmit their power by A. C. Thus we need to transform A. C. to D. C. and we do so by a certain form of dynamotor called a *Rotary Converter* or a *Rotary.*

The New York Central has a dozen large ones in its sub-stations; the Interborough Rapid Transit Co. of New York has 83 of moderate size.

A rotary looks like a dynamotor but has a collector or slip rings like an alternator at one end and the regular commutator at the other.

They often have small motors fitted on the same base to start them up. After being once started they run all right.

Fig. 169 shows the D. C. or output end and Fig. 170 shows the A. C. or intake end of a rotary, the starting motor being clearly shown in each figure.

There is only one winding on the armature core, both commutator and collector are connected to it.

The reason the A. C. does not pass through machine to the D. C. lines is because the commutator rectifies the A. C., i. e., lets through all the + part unchanged and reverses all the — part as it lets it out to the D. C. circuit.

The average pressure of an A. C. is of course less than its highest pressure, and voltmeters read the average. It is the greatest pressure however which gives the pressure to the D. C. end of rotary. It is due to this that a 460 volt A. C. will produce by means of a rotary a 660 volt D. C.

A rotary looks smaller than a generator of equal

power and this is so. The rotary does very little work, so it need not be made very heavy and strong.

Rotaries have a tendency to shift in speed running fast and slow; this is called "hunting." It is prevented by heavy copper straps around the ends of the field poles and bars of copper laid in slots of the pole piece.

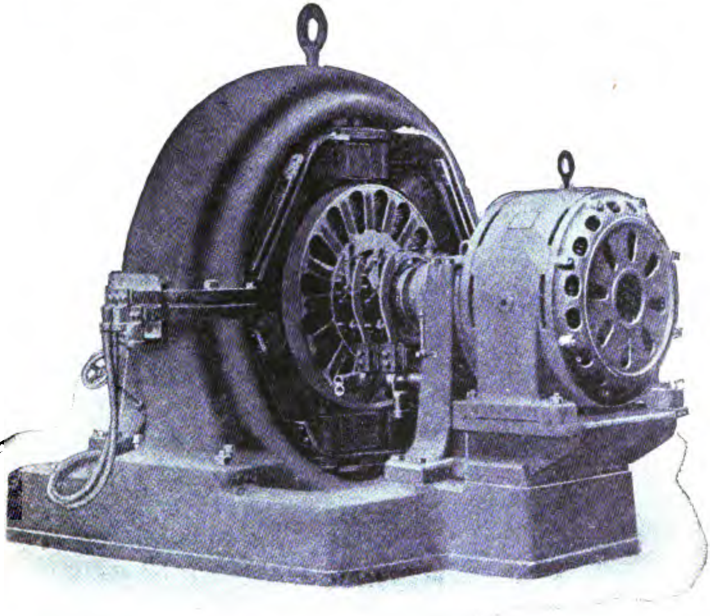

Fig. 170. Collector End of Rotary Shown in Fig. 169. Motor for Starting at Right-hand End of Base Plate.

These copper strips have eddy currents in them each time the speed changes, and the effect of these eddy currents on the armature is to bring it back to normal speed.

Alternating current motors can be built to start themselves like D. C. motors, but rotaries are often started by motors or from their own D. C. ends as direct current motors. In this latter case the A. C. line is thrown on when machine is up to speed. The A. C. then begins to run machine and D. C. power is delivered from the commutator *A. C.*

The transformation of A. C. is the simplest operation in electrical engineering. No moving machinery is needed. The same principles which govern the action of an induction or medical coil operate a transformer.

Electro-Magnetic Induction.

When a dead or idle circuit is approached by a magnet there is a current induced in the idle circuit.

Even should the magnet remain stationary if its strength changes a current is generated in the idle circuit.

The complete set of facts is:

If a dead and loaded circuit approach each other;

If the current in loaded circuit increases;

Then a current is induced in the dead circuit in the opposite direction to the current in loaded circuit.

If a dead and loaded circuit recede from each other;

If the current in the loaded circuit decreases;

Then a current is induced in the direction of the dead circuit in same direction as current in loaded circuit.

As long as the motion or the change of current lasts, so long will the induced current last, and no longer.

Furthermore the ratio of the pressures in the loaded and now alive circuit will be the same as the number of

turns of wire in the two coils which are acting on each other.

If in Fig. 171 A represents the alternator, B its brushes and D and E the mains to the transformer H. This transformer consists of a core of iron C on which are two windings. The coil P is called the primary and is connected to the main from alternator. The other coil S is called the secondary and to it the load is connected.

Whatever the voltage of alternator A that of the secondary circuit F. L. G. will be three-eighths of it

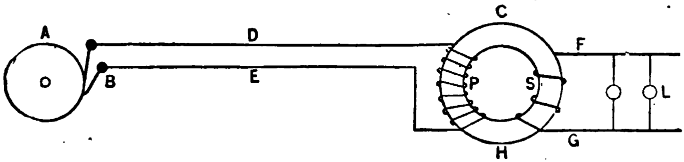

Fig. 171. Diagram of Alternator, Line, Transformer, and Secondary Circuit.

because there are 8 turns on primary and 3 turns on secondary. The power in the secondary circuit is practically the same (minus the losses) as is given out by alternator, hence the primary current is low and wire is small. The secondary current is large so wire is large.

Since one kilowatt can be a combination of a large current and small pressure or small current and large pressure, it is evident that the transformer simply transfers the power, and transforms the voltage and indirectly the current.

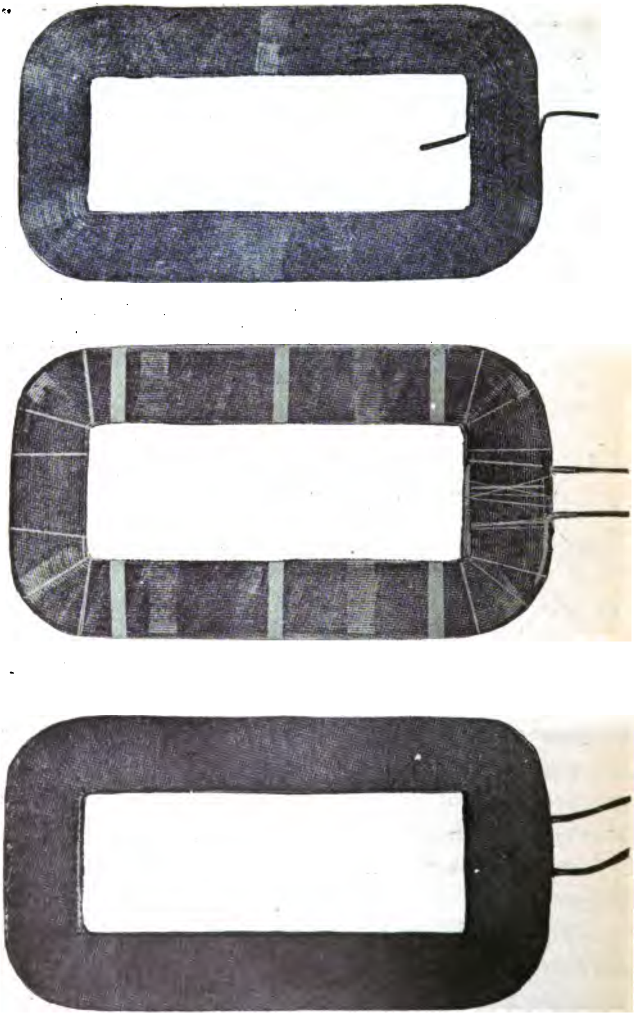

Fig. 172. Transformer Coils in Wound, Bound and Taped Stages of Completion.

Remembering the power formulas in this way $W = Ec$ or eC helps one to grasp the action of transformer.

This transformer (Fig. 171) lowers the voltage and is called a step down transformer.

When the secondary is connected to the alternator the transformer raises the voltage and is called a step up transformer.

The coils of a transformer must be very well insulated. After winding they are bound to keep them in

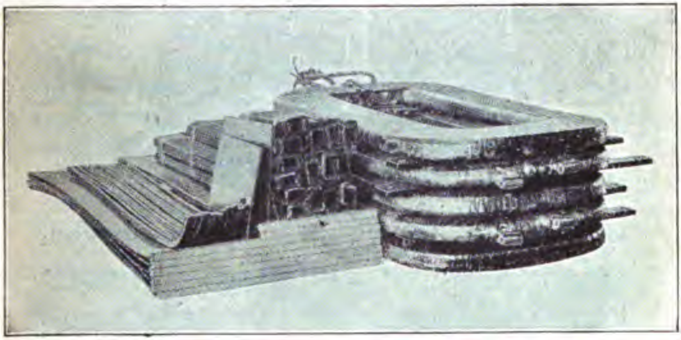

Fig. 173. Coils, Air Ducts, and Separators for Transformer.

shape and then wound with linen tape or varnished cambric cloth. Fig. 172 shows a coil in the three stages of completion.

In Fig. 173 is shown a set of completed coils, together with the ventilating ducts and mica barriers sufficient for one leg of a transformer.

Fig. 174 shows the two legs of a transformer, which form its iron core, each over half-filled with coils. The coil is made of sheets of soft iron.

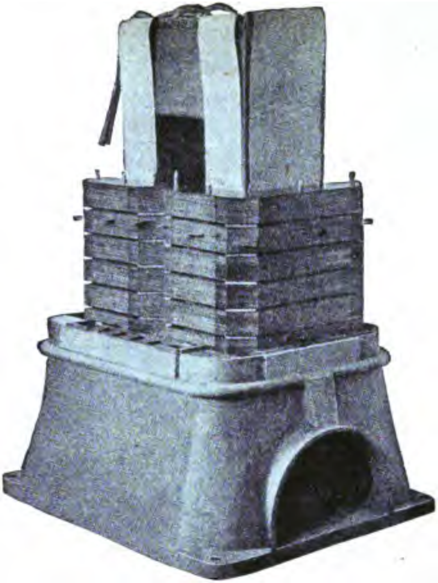

Fig. 174. Interior Construction of an Air Blast Transformer.

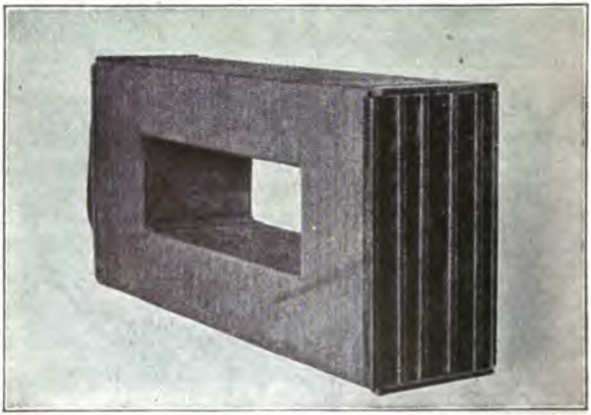

Fig. 175. Set of Coils Made up Ready to Be Placed in Transformer

Fig. 175 shows the manner in which sets of coils are sometimes bound up to be placed in transformer as one coil.

Exciting Current.

The Exciting Current being also called by various other names, such as leakage current, open circuit current, and magnetizing current, is a very important thing.

In order that a transformer may be ready to do its work it is always connected to the line. This means that the primary coil is always magnetizing the core if no current is drawn from the secondary.

This steady flow of current to excite the primary is the price we have to pay for having the transformer continually ready for service.

A transformer should therefore never be left on a line unless it is needed.

Efficiency of Transformers.

The losses in transformers are less than any other piece of electrical machinery or apparatus; 98% of the intake being delivered in the larger sizes as used in railroad sub-stations or power houses, when fully loaded. Unfortunately they lose about the same amount of power at all loads.

A 100 K. W. transformer loses 2 K. W. at full load, its efficiency is then $98 \div 100 = 0.98$. At half load it loses 2 K. W. but is only carrying 50 K. W. so (its losses are now equivalent to 4 K. W. on a 100 K. W.) its efficiency is $48 \div 50 = 0.96$.

At quarter load it takes in 25 K. W., loses 2 K. W., so its efficiency is $23 \div 25 = 0.92$.

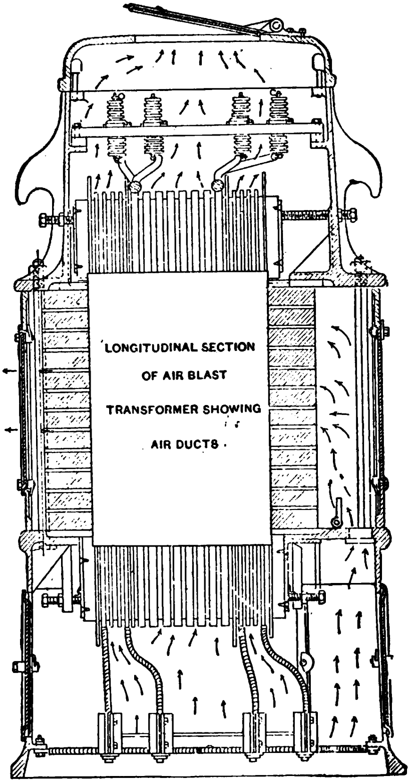

Fig. 176. Air Blast Transformer.

By clever designing transformers are built to be most efficient at three-quarters load. They are a little less efficient at half and full loads, and still less at quarter load and quarter overload, but never fall below 95%.

Cooling Transformers.

Small transformers hung up on poles are cooled by surface radiation only.

Medium sized ones are filled with oil. This conducts the heat to the iron case and also acts as an insulator.

The oil will also flow in and fill a break in the cloth or mica after a puncture.

Air blast avoids the danger of oil in case of fire or flame due to short circuits. They are cheap as a transformer may be much more heavily loaded when cooled by the air blast, and the blower only consumes 1/10 of 1% of the full load output of transformer.

Fig. 176 shows the interior construction of an air blast transformer and Fig. 177 shows how they are installed.

Water Cooled. These are the smallest and cheapest transformers to build but not so cheap to run as the air blast.

The cases are filled with oil which absorbs heat from coil. Pipes are run through the oil, in which cold water is circulated.

In a water power plant where the head of water would render pumps unnecessary the water cooled type would certainly be the best.

Auto-Transformers.

These are only applicable to certain cases.

The idea is shown in Fig. 178. The same coil of wire A to B is used as primary and secondary, the whole

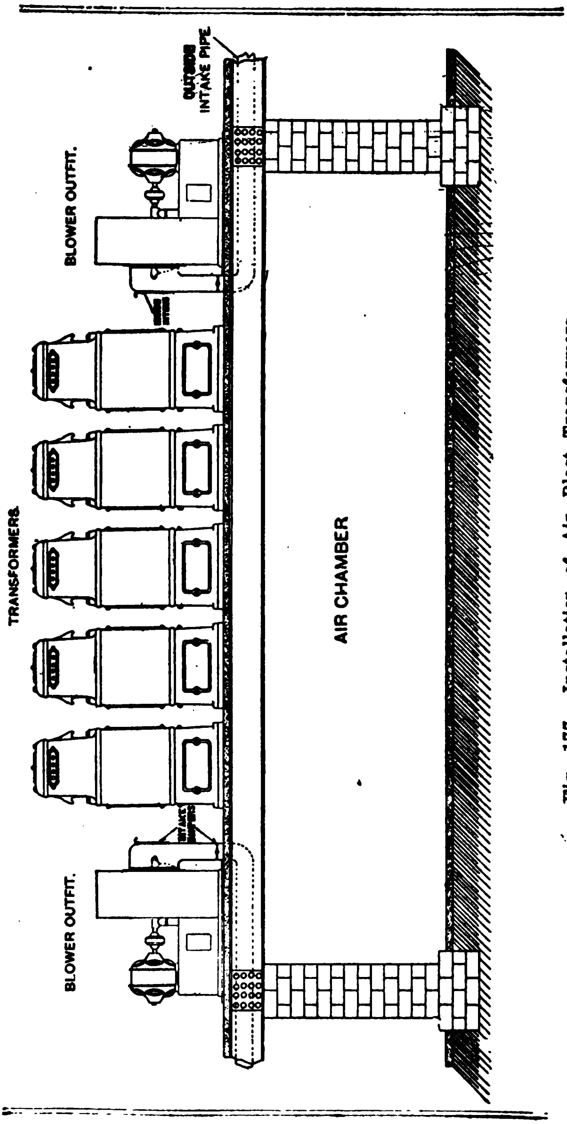

Fig. 177. Installation of Air Blast Transformers.

being the primary and portions as C to D, D to E, or C to E being used as a secondary.

They are only used where the primary voltage is fairly

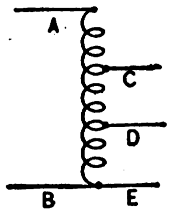

Fig. 178. Diagram of Auto-Transformer or Compensator.

low and the secondary voltage is not less than one-fifth of the primary voltage.

They are used instead of resistances to start A. C. motors.

LESSON 24.

THE DYNAMO.

The dynamo is a machine for transforming mechanical energy into electrical energy, by use of the principles of electro-magnetic induction. These principles were discovered by Faraday. You may repeat his experiments for yourself.

Direction of the Induced E. M. F. In front of you on the table lay a magnet with its N-end projecting over the edge. Take a copper wire and connect its two ends to a galvanometer or pressure meter; usually called a *Voltmeter.* Stretch a portion of this wire between the right and left hands, and move the wire rapidly down in front of the N-end of the magnet at right angles to lines of its action. There will be induced in the wire a pressure or *Electro-motive force* which will send current through the wire from your right hand to your left. The galvanometer will give a deflection showing the flow of current.

This deflection is not a permanent one, the needle instantly dropping back to zero, proving that only a momentary current was produced.

If the experiment is tried moving the wire upwards the direction of the momentary circuit is reversed.

With a downward motion in front of a S-pole we get a left to right current.

Hence, starting with a certain polarity and direction of motion, changing one changes the direction of the induced current, while changing both the polarity and the direction of the motion does not reverse the current.

Now hold the wire a foot away from the magnet and directly opposite it, moving the wire up to the magnet and back again, keeping the distance from the wire to the floor the same, so that the motion shall be parallel to the flux. No E. M. F. is generated in this case.

An electromagnet would do as well and probably better as they are usually stronger than permanent magnets.

The value of the Induced E. M. F. depends on the following:—

1. The greater the strength of the magnet the greater the E. M. F.

2. The more rapidly the wire is moved, the greater the induction.

3. The larger the number of turns in a coil of wire the greater is the E. M. F. induced in it.

The induced E. M. F. therefore depends on the *flux;* the *speed of cutting* this flux, and the *number of wires* cutting this flux.

A dynamo reduced to its simplest form is a coil of wire arranged so as to cut the magnetic flux of an electro magnet, thus producing an induced electromotive force.

A dynamo therefore does not generate electricity, but pumps up a pressure as does a water pump, thus causing the electricity to flow through the circuit, which is called a current.

The current flows through the dynamo and the external circuit in *series,* hence the greater the current the larger must be the dynamo and the heavier the wires of the external circuit.

Since the E. M. F. (electromotive force) can be produced almost entirely by speed of the machine, the voltage at which the current is delivered does not affect the weight of the machine very much.

It is also evident that the faster a machine is driven the smaller the magnets can be and yet the same E. M. F. be produced. This is why high speed generators weigh less than low speed machines. The usual 600 volt railway generator weighs 11, 13, or 16 pounds per ampere of current capacity.

The railway generator whose voltage is 600 and whose resistance is 0.025 of an ohm, would give a current which can be calculated by Ohms law.

$$\text{Amperes} = \frac{\text{E. M. F.}}{\text{Resistance of generator plus resistance of the external circuit.}}$$

If we allowed the external resistance to fall too low by attempting to operate too many locomotives at the same time, the current drawn would generate a great amount of heat while passing through the machine. The amount of this heat can be calculated by the rule.

Heat in Watts is equal to the Square of the current multiplied by the resistance of the generator.

If we build an 11-ton generator and load it too heavily, that is, put 4000 amperes on it; it will have C^2R

watts of heat or 16,000,000 x 0.025 equal to 40 K. W. (kilo watts) to dissipate. Now a machine like this has such a small surface that it cannot radiate 40 K. W. of heat to the air, whereas if a heavier machine had been built, one of 22 tons, it could have gotten rid of the heat. Moreover the copper wires of the 22-ton machine being larger than those of the light machine, the resistance they offer is less, and there will be less heat generated. Thus the heavier machine will run cooler than even the light machine properly loaded.

The danger in overheating of generators is the damage done to the cotton insulation of the wires, due to scorching, and the melting of the shellac varnish between the layers of mica. The mica itself stands the heat very nicely. Any overheating of the armature and the commutator is at once conducted to the bearings.

To prevent the generation and retention of too much heat it is customary to allow 700 C. M. (circular mils) of copper for each ampere of current and to design the shape of the coils of wire so that they will have one square inch of surface for every two watts of heat to be gotten rid of.

The generator must be protected by fuses (which will melt) or by circuit breakers (automatic switches opening at a definite current) which will open the circuit and prevent the further flow of current in case of an accidental low resistance or *short circuit,* as it is called, which would otherwise draw a very heavy current and *burn out* the dynamo. The armature is the part that suffers first.

In talking about dynamos or generators (the two names are used for the same machine) we use the words

E. M. F. and *voltage.* By the E. M. F. of a dynamo is meant *the total pressure generated by the armature.* As the current flows through the armature and field circuits of a railway generator it encounters the *internal resistance* of the generator and pressure is lost according to the rule: Drop in pressure is equal to the product of the current and the resistance. Hence the current as it flows out of the generator is at a reduced pressure; and this pressure at which current is delivered to the switch board, is called the terminal voltage or simply the *Voltage* of the machine. For the generator like above Drop=C x R=2000 x 0.025=50 volts.

If we intend to deliver power at 600 volts it will be necessary to design the speed and the magnetic flux to produce a pressure of about 650 volts.

If a voltmeter be applied to the brushes of a generator just ready to go into service, but not yet carrying any load, the reading obtained is called the E. M. F. When the switches are closed and the generator furnishes power to the line the reading of the voltmeter will drop and its reading is called the *Voltage* of the machine.

We often speak of current being drawn from the dynamo. The generator keeps a steady pressure on the line of 600 volts and the flow of current is regulated by the load in the following way:

One locomotive hauling a train at speed will have a resistance of 0.3 ohm and will draw 600 divided by 0.3 or 2000 amperes.

It would be more accurate to say 2000 amperes are allowed to flow. This locomotive is the only path for current to pass from the feeder (third rail) to the return (rails). When two locomotives are in use there are two

paths between the feeder and the return. The conductivity between conductors has been doubled and the resistance halved. Double the previous current now flows.

In this way we get the current desired by lowering the resistance, and as the current passes it performs the work.

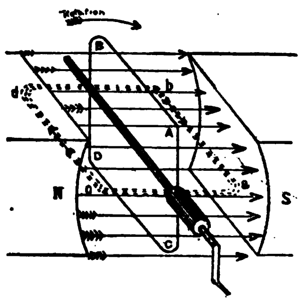

Fig. 179. Direction of Induced E. M. F. in Dynamo.

Two locomotives draw twice the current of one, hence their conductivity is double that of one, and their combined resistance is half of one.

The conductivity of three locomotives is treble, so their combined resistance or Joint Resistance is one-third that of one.

In the usual type of railroad generator, the revolving part is the armature and the stationary part the field magnets. Fig. 179 shows the elements of a dynamo, and as the loop is rotated there is an E. M. F. generated in it.

While the loop is coming into and passing away from the position ABCD, there is no E. M. F. generated, for

the motion is parallel to the flux. As the loop moves towards the position ABCD by a uniform rotative speed it cuts the lines of force faster and faster, for first it cuts in an oblique manner but as the loop comes into the position of abcd the loop is moving straight across the flux. Hence the actual number of lines cut per second is least at ABCD and gradually increasing becomes greatest at abcd; thus producing an E. M. F. of varying value.

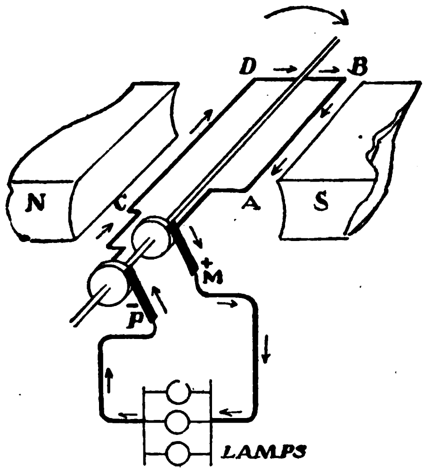

Fig. 180. The Simple Alternating Current Dynamo. Brush M Is Positive.

During this quarter of a revolution the wire BA has moved down in front of a S-pole inducing an E. M. F. tending to send current from B towards A. The other part of the loop CD has moved upward in front of an N-pole inducing an E. M. F. tending to send current from C towards D.

These results are in accordance with the experiments described at the beginning of the lesson. Remember that in applying the rule you must *face* the pole.

This action is repeated during the next quarter of a revolution, and when finally the coil is in the position ABCD with AB at the bottom the pressure is again at zero.

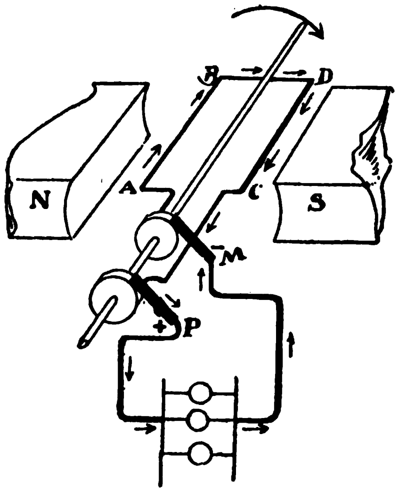

Fig. 181. The Simple Alternator, Shows Coil at One-half a Revolution from Fig. 180. Brush M is Now Negative.

The value of the E. M. F. has started at zero, risen to a maximum, and decreased to zero again. This gives a fluctuating current or pulsating current in the external circuit.

When AB rises in front of the N-pole the E. M. F. will be in the direction of from A to B, while before

it was from B to A. During each revolution of the loop the current flows one way half the time and then is reversed and flows the other way.

This is what happens in the armatures of all dynamos whether alternating (A.C.) or direct (D.C.) current types.

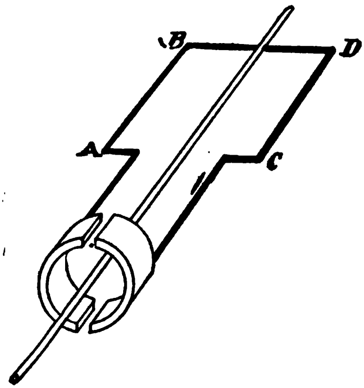

Fig. 182. An Armature Coil Connected to a Two-part Commutator, so as to Deliver Direct Current.

When we wish to utilize the current flowing in the loop of Fig. 179, we attach two collector rings as shown in Figs. 180 and 181, which gives us an A. C. generator or an *Alternator.* For a D. C. generator or simply *Generator,* the ends of the loop are connected to one ring split as shown in Fig. 182, whose halves are insulated from each other and from the shaft. Two brushes are placed as in Fig. 183. In this case the alternating E. M. F. will be *reversed* or *commuted* at the proper instant and there will be a one direction E. M. F. impressed on the external circuit. The split ring is called a *Commutator.*

THE ALTERNATOR.

In Figs. 180 and 181 are shown two positions of the loop on the armature of an alternator. The collector rings are insulated from the shaft and each other by mica. The terminals of the loop are soldered or riveted (sometimes both) to the rings and current is led to the external circuit containing the lamps by stationary strips of copper which form a sliding contact with the rings.

Fig. 183. Cross Section of Simple Commutator. Black Represents Copper; White Space Is Mica Insulation.

Look at Fig. 180 and notice that during the first half of the revolution of the loop ABCD, the direction of the E. M. F. in AB is from B to A, and in CD is from C to D.

The current flows from the brush M to the lamps so that M is positive.

Looking at Fig. 181 note that the wire in front of the S-pole is still positive, but that it is now the wire CD instead of AB, so P is the positive brush for the second half of the revolution. There are two reversals of the current per revolution.

The number of *alterations per minute* is the speed in revolutions per minute multiplied by the number of poles.

The number of *cycles* is found by multiplying the speed in revolutions per second by the number of pairs of poles. The number of cycles is usually spoken of as the *Frequency* of the alternator.

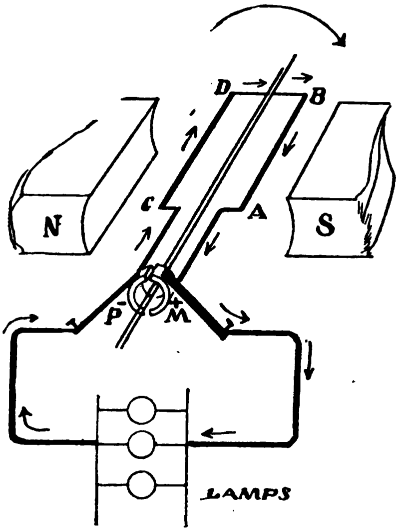

Fig. 184. Simple D. C. Generator. At This Instant the Brush M Is Positive.

The usual frequencies are for power 25, for motor circuits, and arc lamps 66, and for incandescent lighting 133.

THE DIRECT CURRENT GENERATOR.

In Fig. 184 is shown a loop and a two part commutator of a D.C. generator.

Since the wire AB is moving down past a S-pole, the current flows from B to A and out of the brush M,

which is called the positive brush. In wire CD the current flows from C to D, making P the negative brush.

After half a revolution the wire CD is over where AB was, and is now delivering current towards the external circuit instead of away from it; *but CD is now connected through its commutator bar to brush M instead of to P so that the brush M is still positive.* (See Fig. 185.)

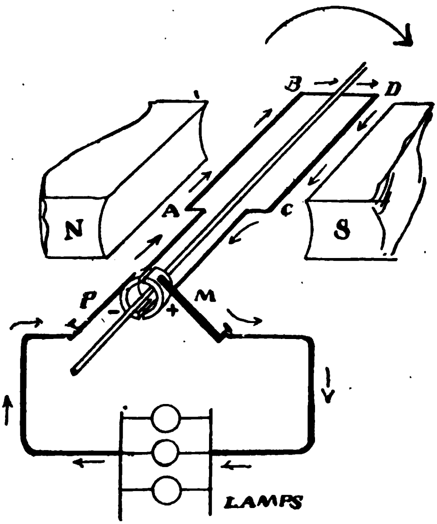

Fig. 185. Simple D. C. Generator. The Armature Has Made Half a Revolution, but Brush M Is Still Positive.

This arrangement of commutator bars and brushes performs the duty of connecting the brush M to that part of the winding, and only that part which is moving down in front of a S-pole. As long as the wire AB moves up in front of a N-pole the commutator connects

it to brush P, but as soon as it begins to move down in front of a S-pole it is immediately disconnected from P and a connection made with M.

To increase the E.M.F. The greater the field strength the greater the E.F.M. and the higher the speed the greater the E.M.F.

When the speed has been raised until the surface of the armature is traveling at the rate of 3000 ft. a minute* no further increase is made, lest the bursting stresses become too great.

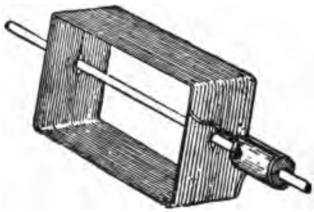

Fig. 186. A Single Coil Armature of Many Turns.

In order to further increase the E.M.F. more *turns* or *loops* of wire must be wound on the armature. A coil of 16 turns as in Fig. 186 will give an E.M.F. 16 times as great as a coil like Fig. 182. Looking at Fig. 187 will convince you of this.

Suppose the direction of rotation to be the same as the hands of a watch (or as we say, *clockwise*) when viewed from the commutator end of machine; then the

*This is called the Peripheral Speed of the armature and is calculated by this rule:

P. S. equals 3.1416 x D x R. P. M. where D is the diameter of armature in feet and R. P. M. is the revolutions of the armature per minute.

E. M. F.'s induced in the successive portions of the wire will be as shown by the arrows, and will add to each other, impressing a high E.M.F. on the brushes. We say that these turns of wire are all in *series.*

Any betterment of the magnetic conductivity of the frame of the machine will increase the E.M.F.; by producing a greater flux per pound of copper on the field magnets. Hence the winding of the armature inductors (wires) on a core of very softest iron is an economic necessity, resulting in either a higher E.M.F. or a reduction of the expense for copper in the field coils.

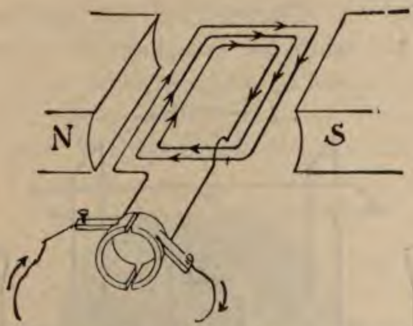

Fig. 187. An Armature Coil of Many Turns Showing How the Induced E. M. F. of Each Turn Adds Itself to That of Other Turns.

These cores are called *Drum cores* when the central hole is just large enough for the shaft and the insulation around it (Fig. 188); and are named *Ring cores* when the internal diameter of the ring is much larger than the shaft. (Fig. 190.) The armature in Fig. 191 has a ring core, but the end plates being in position, the large hole is concealed.

These cores are built up of a great many punchings of soft iron from 15 to 40 mils thick, pickled so as to rust them a little. Every tenth one is varnished or tissue

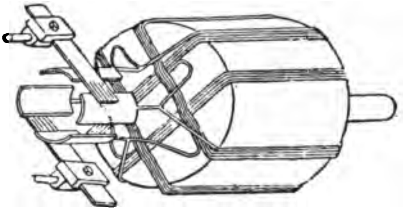

Fig. 188. Drum Winding on a Drum Core. Four Coils and Four Commutator Bars. For Direct Current.

paper pasted on. The rust, varnish and paper are all insulators and when the punchings are assembled in a

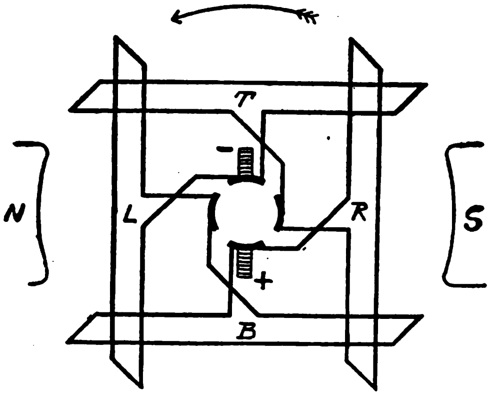

Fig. 189. Diagram of Fig. 188.

core prevent currents called *Eddy currents* from flowing from one end of the armature to the other and heating it.

These cores are sometimes *smooth* but more frequently are *slotted* with the wires laid in the slots.

About 10 to 15% of the length of the core is insulation, and about 50% of the surface is slots containing the inductors.

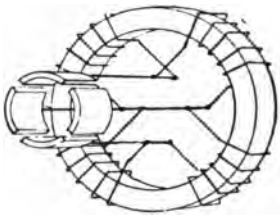

Fig. 190. Simple Gramme Ring Winding.

To get a Continuous E.M.F. While a single coil of many turns produces a high E.M.F., which by a two part commutator is always applied to the external circuit

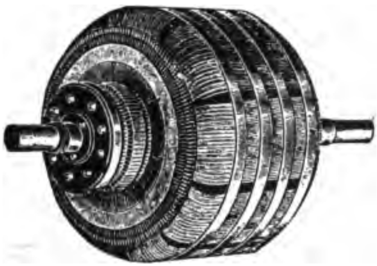

Fig. 191. Eight Section Eighty Coil Ring Winding on a Smooth Ring Core, with Eighty Bar Commutator. For Direct Current.

in the same direction, yet this coil passes through all the changes in voltage mentioned in connection with Fig. 179.

Examine the ring winding (invented by Gramme) of Fig. 190, which is wound on a ring core made up of soft iron punchings 25 mils thick.

The wires on the outer surface are *active,* having E.M.F. induced in them, and are called *armature inductors.* The rest of the wire is *dead* wire and only useful to complete the circuits between inductors.

Notice the connections between commutator bars and winding. Number the coils and commutator bars with a pencil, sketch in the two magnetic poles and the two brushes. Imagine the armature to rotate clockwise and figure out the value of the voltage at the brushes during different parts of a revolution.

In Fig. 192 we have the same windings with eight coils and eight commutator bars. In Fig. 191 the armature as diagrammed in Fig. 192 is shown completed with its four bands. These bands are from 12 to 25 convolutions of phosphor-bronze wire in sizes varying from No. 20 up to 14 laid on tightly over a mica insulation and sweated with solder all the way round.

In Fig. 192 you will notice that the complete winding can be divided into two parts, one influenced by the N-pole, the other by the S-pole standing at the commutator end. The N-pole side moving upwards has its E.M.F. in direction from back to front of armature *through the inductors;* the S-pole side has E.M.F. in direction from back to front of armature *through the dead wire.*

In winding the armature the wire is laid on in a continuous spiral as shown. This makes the E.M.F. in each half of the armature in series, and allows the current to flow from one coil to another, except at the points where the N-half and S-half of the armature

meet. Here the E.M.F.'s oppose and if wires were connected for an instant to the winding, as shown in the picture, the two opposing E.M.F.'s would both force electricity out into the wire at the top of the armature and draw it in at the bottom as shown by the arrows on these wires. This will cause a current to flow in the external circuit.

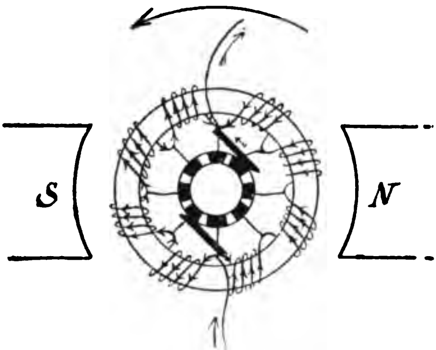

Fig. 192. Eight Coil Gramme Ring Winding, with Eight Part Commutator.

If the junctions of the coils are connected to eight commutator bars (one bar per coil) and connect the ends of the external circuit by brushes to the commutator bars which are midway between the N- and S-poles, then each half of the armature separately generates an E.M.F. and delivers current to the external circuit.

Suppose the armature to be revolving at the highest safe speed. Each inductor will move past the magnet poles at a speed of 3000 ft. a minute. With pole pieces 5 x 8 inches and a *flux density* of 90,000 lines per square inch, the *total flux* will be 5 x 8 x 90,000 or 3.6 million lines.

The armature may be 9 inches in diameter, which gives its rotative speed 1270 (nearly).

For R.P.M.*=P.S.†÷(3.1416 × diameter).

$$= \frac{3000 \times 12}{3.1416 \times 9}$$

$$=1270 \text{ nearly.}$$

which R.P.S.‡=21 nearly.

An inductor therefore cuts 3.6 million lines of magnetism twenty-one times a second, which is equivalent to cutting 75.6 millions once per second.

Since the cutting of 100 million lines per second by an inductor induces 1 volt pressure, each inductor on this armature revolving in this field will produce 75.6÷100 or ¾ of a volt (aprox.).

The 4 coils of 4 inductors each (Fig. 192) on the N-half of armature being in series produces 3 volts per coil or a total of 12 volts *which is the E.M.F. of the generator.*

The S-half of the armature also generates a pressure of 12 volts, which is not added to the pressure of the N-half, being in parallel with it. An inspection of Fig. 192 shows that they oppose rather than add to each other; but an outlet being provided they turn aside through it, and send current separately and independently towards the outside circuit.

If the armature is wound with No. 10 A. W. G.,§ the

*Revolutions per minute.

†Peripheral speed.

‡Revolutions per second.

§American Wire Gauge. A table of sizes and properties of the sizes of wire according to the Brown & Sharp or American Gauge will be found in Lesson 18.

diameter of which is 0.102 inch or 102 mils, its area is 102 squared equal to 10,404 c.m. Allowing 700 c.m. per ampere, it will carry 15 amperes, without too much heating.

Since each side of the armature delivers its own current to the brushes, the safe current output of this generator is 30 amperes.

Suppose there are 250 ft. of this No. 10 wire on this armature. The resistance of the wire from the wire table is 1.02 ohms per 1000 ft.

The resistance of *all the wire* on armature is 0.255 ohm, and the resistance of the wire on each *half* of the armature is 0.128 ohm.

But the two halves are in parallel so *the resistance of the armature as measured from brush to brush* will be half of 0.128 or 0.064 ohms.

The drop or loss of pressure in armature will be $C \times R$ or 30×0.064, equal to 1.92 or say 2 volts.

This machine being a *shunt generator,* the main current does *not* pass through the fields, and there is no further voltage loss.

The E.M.F. of this dynamo is 12 volts and its *voltage* 10 volts. Its output in watts will be $10 \times 30 = 300$ watts or 0.3 kw. This is the *rating* of the generator.

The generator will carry this load 22 hours a day without getting more than 90° Fah. hotter than the surrounding air.

A properly proportioned machine will stand a 25% overload for half an hour rising an extra 30° in temperature, and it will stand a 50% overload for one minute without being damaged by the heat.

Drum Windings.

The extra labor involved in passing the dead wire through the bore of a ring core is avoided by going back to first principles again and placing on the core (either drum or ring) a number of coils shaped as in Fig. 186, producing a winding as in Fig. 188.

It is to be noted that the inductors lie entirely on the outer surface of the core and that the percentage of dead wire is less than in Fig. 190.

For a long, small diameter armature drum winding uses the least wire; while for a short, large diameter core the ring winding will require fewer pounds of copper.

Take Fig. 188 and mark in pencil as directed, using Fig. 189 as a guide. In order to make the diagram in Fig. 189 clear, it has its proportions wrong. The dead part of the wire is drawn very long and the active part very short. The reverse is true of an actual winding.

Mark the top horizontal coil of Fig. 188 T, the bottom one B. Mark the right and left hand vertical coils L and R. Mark the upper brush negative and the lower one positive.

The left side of the armature is the N-pole side and the right the S-pole side; then we know that the armature is revolving anti-clockwise (else the upper brush would be positive).

The E.M.F.'s on the N-side and S-side of coil T, just as in Fig. 187, are in series and add producing a current flow towards the lower (positive) brush. The current passes through the inactive (dead) coil R in order to get to positive brush.

At the same time the E.M.F.'s in coil B add up and passing through the dead coil L drive current out of lower brush.

The value of the E.M.F. is eight times that which one inductor can produce. For the active coil T has 4 loops, i. e., 8 inductors in series, as also has the coil B. Suppose T produces 8 volts, the two coils T and B are in parallel and do not add their E.M.F.'s.

The coils L and R are dead, L being in series with B and R in series with T, but they produce no E.M.F. At the present instant they are but a wasteful resistance, their value, however, will be soon seen.

When the armature has moved about 1/8 of a revolution, you will find that T is cutting flux slantingly and that R, which is in series with it, is beginnng to cut flux also. T is only 3/4 active, producing say 6 volts, and R is not totally dead but 1/4 active, producing 2 volts. Hence the voltage of the machine is still 8.

At 1/4 revolution R is doing full work and B is dead and in series with it, while T is dead and L in series with it is at full activity. Now R and L produce the E.M.F.

The student must revolve Fig. 189, using slips of paper as brushes to gain a full understanding of these actions.

The current enters the armature through the upper brush, splits and passes through the armature by two parallel circuits, one containing T and R in series and the other containing L and B. During a revolution these coils interchange places, but two coils are always in each circuit.

When 6 amperes flow in the external circuit, the No. 16 wire of the armature is not overheated, as it only has

to carry 3 amperes (half of 6), which it is well able to do. It has 2583 C.M., and which is more than 3×700 C.M.

Self exciting of a Dynamo. When a dynamo is standing idle the field magnets are weakly magnetic due to residual magnetism.

Let the armature revolve and in a shunt or compound machine open, in a series generator close the external circuit.

A few volts will be generated and cause a current to flow through the fields, hence the magnetism will increase and more voltage will be induced. This voltage will send increased current through the shunt field and cause more volts to be induced.

The machine is now *"building up."*

As more and more magnetism is put into the fields, it becomes harder to get any more in as the iron is approaching *saturation* and there is more and more *leakage.*

Hence at a certain point, depending on the design of the machine, the difficulty of increasing the magnetism being added to the effect of the leakage just balances the tendency of the voltage to be increased. If nothing else is done the voltage of the dynamo will remain constant.

In the series field is passing all the current drawn from the machine and the field strength and voltage tend to increase. This increase is opposed by the C. R. loss in armature and field, and the effect of the increasing field density. The net result is a *building up* of the voltage and if the load is not changed the voltage of the machine will remain constant.

Regulation. If now in the shunt generator you close the external circuit an extra current (very large in pro-

portion to the field current) is drawn from the armature and causes a C R loss.

A lower voltage is thus impressed on the external circuit and to make matters worse, also on the field. Hence the field weakens and the added results of C R loss and weaker field is a considerable drop in voltage for each increase in load.

Resistance must be cut out of field as load increases.

When in the series generator the load increases a shunt should be placed around the field to weaken it, if a constant potential is desired.

Position of the Brushes. In order that one set of brushes may take away from and the other set deliver current to the generator in a bipolar machine these sets are on opposite sides of the commutator.

In some dynamos when the inductors come out of the slots, one goes straight on to a commutator bar and the other is bent over to its proper bar. This puts the brushes in line with part of the coil and they will be found half way between the pole tips.

It is usual to bend both inductors as they leave the slots and connect to bars half way between the slots. Then the brushes will be found opposite the middle of the pole piece.

In dynamos and non-reversing motors the brushes are a little distance away from the points mentioned, but in reversing motors are exactly at these points.

If you will consider that a multipolar dynamo or motor is merely a lot of bipolar fields which for economy of material are working on one large armature, the placing of the brushes on such machines will be clear to you.

The alternate brushes are of the same polarity and there is usually a set of brushes for each field magnet.

The placing of the brushes on the commutator with a certain relation to the winding is necessary as a reference to Fig. 193 or to the diagram of any winding will show you that the brush while collecting current is at the same time *short circuiting* one of the coils.

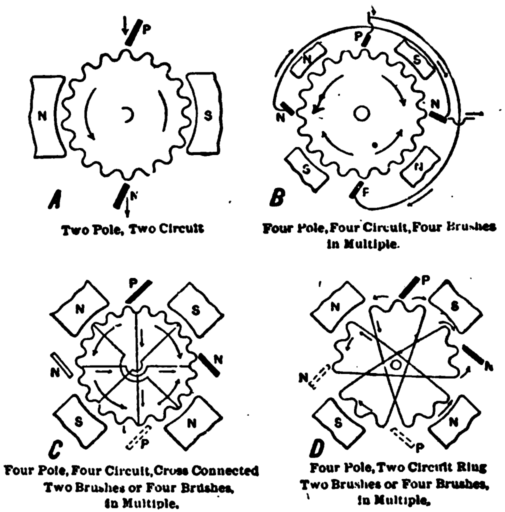

Fig. 193. Showing the Number and Position of Brushes on Different Armature Windings.

The black brushes are the ones actually used, the dotted ones being dispensed with on account of the particular winding.

In order that an excessive current may not be generated in this short circuited coil it must be out in the interpolar space at the time the brush touches the two bars belonging to it.

Sparking. When a current is broken there is always a spark, which is greater the more turns in the wire and the more iron within these turns. That is, the more *inductive* the current the worse the spark.

The conditions are right for excessive sparking in a machine, for the circuit is *inductive* and although the circuit is not actually broken, the current being merely shifted, yet the result is equivalent to it.

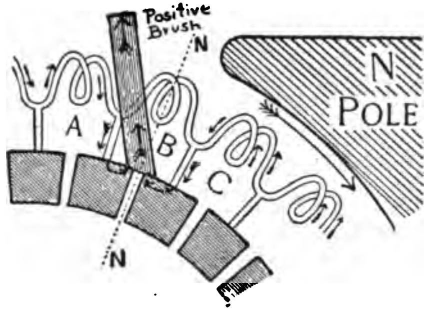

Fig. 194. Showing Position of Brush for Sparklers. Collection of Current.

Looking at Fig. 194 and considering the line N N to be about midway between the pole pieces. The coil B is short circuited but has no current in it because

1st. The field is very weak and the coil is moving parallel to it, so no E.M.F. is generated in the coil.

2d. The currents from the N and S-side of winding enter the brush without going through the coil B.

Coil B has therefore no *current* in it, but being connected to A and C whose potential is high B is *charged*

with electricity, and it is full of *coulombs,** which are at rest.

When the armature revolves as shown and the toe of a copper brush leaves bar 3 the current from C must instantly change over going through B to reach the brush. The coulombs in B which are at rest should instantly move at full speed becoming a part of the armature current.

It being impossible to set the coulombs in B into motion instantaneously it is evident that the current from C encounters *more* than the *ohmic resistance* of the coil B. This extra opposition being called *reactance.*

The path through B being momentarily practically nonconducting the circuit is broken by the brush moving away from the bar, and a spark or arc formed.

The circuit being *inductive* (having turns containing iron) the spark is persistent and holds until the *reactance* of coil B decreasing, it begins to conduct and diverts enough current into the proper path and the arc goes out for lack of current to maintain it.

This *sparking* is avoided in the following way:

1st. Carbon brushes of high resistance are used which, as the part of the brush touching a bar gets narrower, due to the high resistance, throttles the current, gradually forcing it over to the coil B. Hence B does not have to instantly carry *all* the current.

2d. Move the brushes of a dynamo in direction of rotation until they are nearer the pole shoe, exactly as is shown in Fig. 194.

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*A coulomb is a certain quantity of electricity. When a coulomb passes a given point every second a current of one ampere is said to flow.

The short circuited coil B is now under the *fringe* from the pole piece; and is moving obliquely through a stronger field. A small E.M.F. is generated in it.

From the illustration it will be seen that a current in the same, as in C (for B and C are under influence of same pole piece) flows around through B, the bars 2 and 3 and the brush.

By *shifting* the brushes a little to and fro the correct strength of field can be selected and the obliquity at which it is cut adjusted, so that a current will be made to flow in B not only of *the same direction as that in C* but also of exactly the *same value.*

Hence when the toe of the brush slips from bar 3 the current in C instead of running against the *impedance* (the sum of the resistance and reactance) of coil B, finds itself merely falling in behind the flow already established, and there is no tendency to spark.

In a motor the brushes are shifted in opposite direction to the rotation to get to the no sparking position. Hence the positions for sparkless forward or backward running are some distance apart.

It is a mere matter of first cost to produce a machine with absolutely *sparkless commutation* under any conditions. It is the skill of the designers which has (without prohibitive cost) so reduced the distance between these two points that it may be spanned by a thick carbon brush.

The railroad motor of to-day operates in either direction, without shift of brushes, under all loads, and some overloads, without serious sparking. What little occurs is of such small volume and such low temperature that no great harm is done.

Classes of Dynamos.

Dynamos are divided into classes with reference to the manner in which their fields and armature are inter-connected.

The series dynamo. Fig. 195. The same current traverses the field, armature and main or external circuits. The conductors in these circuits are about the same size. The circuits are all in *series.*

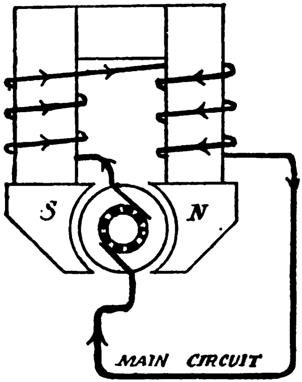

Fig. 195. Circuits in a Series Dynamo or Motor.

This dynamo is used for arc lighting and as boosters for increasing the pressure on a *feeder* carrying current furnished by some other generator.

The characteristic of this type is to furnish power at an increased voltage as the load increases. If sufficient current is drawn to overload the machine the voltage will fall.

The shunt dynamo. Fig. 196. Here the field circuit is arranged as a shunt circuit. The armature and ex-

ternal circuits are in series. The armature current is the sum of the external and field currents. The conductors on the field are very much smaller than those on armature, as they only carry 2 to 5 per cent as much current.

Used for incandescent lamp lighting, mill and factory power.

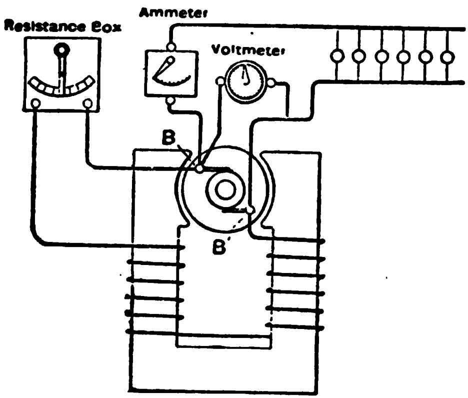

Fig. 196. Circuits of a Shunt Dynamo with Instruments and a Load of Lamps.

The characteristic of the shunt generator is to allow the voltage to fall as the load is increased.

It is evident that only by a combination of these two into a *compound dynamo*, Fig. 197, can a generator be produced which will deliver any power within its rated capacity and yet hold a steady voltage.

The armature is the same as a shunt dynamo, but the fields have two distinct windings, one shunt and the other series.

The series dynamo is often called a *constant current* generator because its tendency is that way, and with a regulator it will furnish a constant current.

The shunt dynamo is similarly termed a *constant potential* generator. For with a regulator it will keep to a constant voltage.

The compound generator will of its own accord, without any regulator, furnish at its terminals or at any distant point on the line steady power, at an absolutely constant voltage.

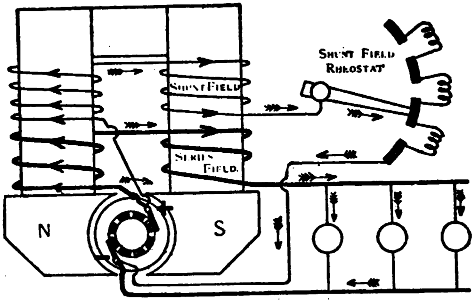

Fig. 197. Circuits in a Compound Dynamo.

In railway service where the amount of power required fluctuates violently, the voltage will vary somewhat, for the generator scarcely has time to adjust itself to the present conditions before the condition no longer exists and a new demand arises.

It is not necessary that the pressure on the third-rail should be absolutely constant, and for this kind of service the compound generator, with the series characteristic predominating, so as to keep a steady pressure *out on the line* is good and plenty.

LESSON 25.

MOTORS.

It might be said that another class of dynamos is *motors*.

Any of the D. C. dynamos and many of the A. C. machines in power houses would revolve and produce mechanical power if they were supplied with the proper kind of current at proper voltage. In fact, one of the troubles that may occur in a power house is to have one out of a set of generators start to act as a motor, thus placing heavier load on all the other machines.

The same electrical machines can be used as a dynamo or a motor; but as most dynamos are *compound* or *shunt* and built for power houses, where there is sufficient, if not plenty of room, and as all railroad motors are *series wound* and placed where there is very little room, it is natural that the dynamos and motors a railroad man sees should not look alike.

The similarity of their electrical action must be remembered so that one may understand that the parts of a dynamo and motor, though a little different in shape, act alike electrically and have the same names.

Comparison between Dynamo and Motor. Since it takes power to force a dynamo armature to revolve while generating current, and none when not generating (field and armature circuits open) we conclude that it is

the action between field and armature magnetisms which causes the dynamo to resist rotation.

To test truth of this remove the armature from the fields and pass current through its conductors *in same direction as the flow was before.* You will find that the armature is a large, strong electro-magnet.

Testing the polarity of the field magnets and of the armature poles you will find that where using as a dynamo, we are forcing a N-armature pole towards a N-field pole. These poles repel each other and power is absorbed by the rotation of the dynamo.

The repulsion of these poles would make the armature rotate if current were supplied to it and the fields, and the steam engine removed.

The difference between ordinary and railway motors is the extreme simplicity of the latter.

Many of the refinements of design and construction which theoretically are necessary, are in railway motors omitted. It being found that for successful operation they are *not* necessary, and by their omission much is gained, i. e., saving in weight, cost, number of parts, absence of complication and ease of repair.

It is not needful to say that parts of a railway motor are put together so as to "stay put."

That motor is best, which with the fewest pounds of material, will with reliability and low cost of repairs propel the greatest number of tons of pay load.

The main differences between all motors and dynamos are the method of starting and the effect of the E.M.F. produced.

Starting Motors.

We can not turn on steam to an engine instantaneously, for it takes time to open the throttle. We do, however, turn it on more slowly than the opening of the throttle compels us, for we wish to give the engine and its dynamo time to get up to speed.

In the same way we must give current to a motor easily, in order to start it. On the closing of a switch the current jumps up to full value so quickly that the motor armature would be brought up to such a temperature as would char the cotton insulation on the winding.

In starting a motor an extra resistance is used, and it is placed either in the main or armature circuit. It is only in use for a few seconds at a time and if well ventilated can be made very small and light in proportion to the current passing.

When applied to small motors where the starting is at infrequent intervals this starting rheostat and its operating drum and handle is combined with two automatic protective devices and contained partly in a latticed iron box and partly on its cover. It is called a *starting box.*

For larger motors doing similar work and for traction or railway work, each of the parts becomes so large that the four pieces are mounted separately. The operating drum, the resistances, the overload release and the no voltage release.

The operating drum is familiar to us all as the *controller* of the street cars.

The *resistance* in the form of cast iron girds held in skeleton frames are fastened under the sills of the cars.

The *overload release* or *circuit breaker* automatically

opens the circuit when a current large enough to damage the motors is accidentally drawn. In street cars this device is usually fastened under the hood over the motorman's head.

No voltage release, a magnetically operated switch or series of switches kept closed by the magnet, thus giving the current access to the motors circuits or the circuits controlling them.

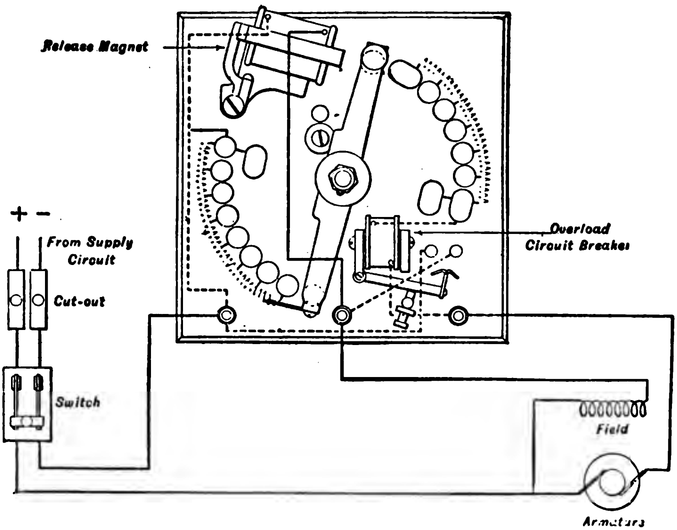

Fig. 198. Starting Box and Connections for Shunt Motor.

If the power is cut off the line the device operates, opening all the circuits leading to the motors, thus protecting the motors from the damage done by applying full voltage suddenly to a motor while standing still.

Fig. 198 shows a starting box with the proper connections ready to start a *shunt motor*. (Off position.)

As soon as the switch is closed there is full voltage on the field, but no voltage on the armature, as the circuit is open at each end of the starting arm.

As the arm is swung clockwise, current flows to armature through a resistance which gradually grows less, until when at right angles to its original position the full voltage is on the armature and the motor operating at full speed.

The hook on the left end of the arm catches on the knuckle at the lower left side of the release magnet and holds the arm in spite of the effort of a coiled spring (not shown) to return arm to *off* position.

Tracing the circuits will show that the release magnet is always energized if the supply circuit is *alive* and switch closed. Should the supply be interrupted the release magnet becomes demagnetized and the upper end of the knuckle is no longer held. The knuckle turns on the pin (with screw head) releasing the hook, and the spring returns the arm to the *off* position.

The motor would have stopped itself, but now it can only be restarted in the proper way.

Consider the arm in the "running position," the *overload circuit breaker* magnet in energized, but the armature* being a considerable distance away the magnet is too weak to draw it up.

Should the motor be overloaded and too much current pass the strength of this magnet is increased so that the armature swings up and jams the jumper in between the two studs shown on the right of the magnet. This completes a *shunt* or by-pass circuit around the release magnet, diverting enough current from it that it weakens and releases the knuckle. The arm then flies back

*Armature or keeper of a magnet; not of a dynamo.

to the *off* position and the circuit to the armature is opened.

The motor is stopped, which may be inconvenient, but it is to be preferred to a *burnt out* armature.

In a railway motor this heavy current would also pass through the fields, but they are better adapted to stand heat and the armature usually suffers first.

To start a motor with this *box*, close the switch and swing the starting arm from *off* to *running* position and let go. The overload circuit breaker may have danced up and down while this is being done. If so, next time swing arm more slowly.

To stop the motor *open the switch*. The motor will slow down and stop. Just before stopping, the release magnet will allow the starting arm to return to the *off* position.

The cutout shown consists of a fuse enclosed in a cardboard tube and designed to melt or *blow* at a current a little higher than that for which the circuit breaker is adjusted.

COUNTER E. M. F.

Counter E. M. F. When the motor is operating all the parts and conditions of a dynamo are present, hence there is a dynamo action which produces an E. M. F. in opposite direction to the *impressed E. M. F.* supplied by the line.*

This is a most important and useful action.

*This I know by using the rule: Place the thumb, first and second fingers of the right hand all at right angles to each other.

1st Thumb in direction of the motion.

2d First finger pointing from a N-pole to a S-pole.

3d Second finger shows direction of induced. E. M. F.

You will see that when we are starting a motor that the faster it moves the more C. E. M. F. it generates. This is why we can not throw full voltage on a motor until it is nearly up to its full speed.

The actual voltage sending current through a motor is the difference between the impressed and counter E. M. F.'s.

The working of this in actual practice is best shown as follows:

Suppose a set of four motors are on a 600-volt line making 460 revolutions per minute with 44-inch wheels. The locomotive they are a part of weighs 100 tons and pulls 350 tons behind it at 60 miles per hour.

It is on a level track and must exert a pull of 17½ pounds for each ton pulled or 6,125 pounds in all.

It must exert through its drivers at the rail head 6,125 pounds for the train behind and 1,750 pounds for its own weight. The total tractive effort is therefore 7,900 pounds (7,875 to be exact).*

At 60 miles per hour a train moves 5,280 feet per minute; so the motors move 7,900 pounds 5,280 feet a minute which is 41,700,000 foot pounds per minute. Since 33,000 foot pounds per minute is a *Horse Power,* we get the H. P. of the motors as 1,264.

The efficiency of the locomotive is 80%, *i. e.,* the motors waste 20% of the intake. Hence 1,580 H. P. is taken from the line.

This is expressed in *Kilo Watts* by multiplying by 746 and dividing by 1,000 giving us 1,185 K. W.†

*With certain problems a foolish amount of accuracy in figuring is a waste of time. Since the condition of the rails is a variable quality in traction work, figuring on the *safe side* is the only sensible way to work.

†There are 746 watts in 1 H. P., and 1000 watts in a K. W.

This being supplied at 600 volts needs 2,000 amperes (1,975).

An ammeter placed in the main conductor of one of the New York Central locomotives will read about 2,000 amperes when pulling train No. 51 or No. 41 along the Hudson River towards Croton, N. Y.

What is it that limits the current in this case to 2,000 amperes, *i. e.*, to 500 amperes per motor? Certainly not the ohmic resistance of them.‡

The resistance of *each* motor is only 0.1 ohm or all four in parallel or multiple is 0.025. The current is limited by the dynamo action of the motors, *i. e.*, by the counter E. M. F.

Each of the motors generates about 1.2 volts per revolution per minute, hence at 460 revolutions per minute the C.E.M.F. of each motor is 550 volts. This neutralizes all but 50 of the 600 volts on the line, and leaves that 50 to send current through the resistance of the motor. Fifty volts on 0.1 ohm gives 500 amperes or 2,000 amperes for all four motors.

Now let the train strike a grade. It will slow down in speed and drawing more current develop in its motors the H. P. required to pull the train.

How can motors whose resistance is fixed draw more current when the line voltage is constant? By means of the C.E.M.F.

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‡By ohmic resistance I mean the actual resistance of the material the conductors are made of. There is another resistance which depends on the rate at which a current *changes*, and has nothing to do with the material. Counter E. M. F. acts like resistance, as it opposes the flow of current. The ***apparent resistance*** of a locomotive drawing 2000 amperes is 0.3 ohm for 600÷0.3=2000. The actual ohmic resistance is 0.025 ohms.

If the speed drops to 55 M.P.H. then the R.P.M. of the drivers (and armature) change to 422, and the C.E.M.F. to 510 volts. Hence 90 volts acting on each 0.1 ohm motor passes 900 amperes, or 3,600 for the whole locomotive.

LESSON 26.

PARTS OF DYNAMOS AND MOTORS.

The following is a short description of the various parts of a *dynamo* or *motor* and an explanation of the terms used in talking about them.

Base. Made of cast iron and supports the magnet yoke and bearings. It is made hollow to save unnecessary weight, and is braced internally with ribs to give strength. It is bolted to a masonry foundation.

Railway motors have no base; the yoke being bolted to the transoms of the truck, either directly or through a spring supported lug.

Yoke. The ring or shell steel casting to which the magnet cores are bolted. Sometimes the cores are placed in the mold and the yoke cast around them.

In *railway motors* the cores are so short that they are frequently cast solid with the shell.

Pole pieces or faces. Generally of cast iron bolted or keyed to the magnet cores. Being greater in area than cores they serve to hold the field coils in place.

In *locomotives* they are sometimes made of sheet iron.

Magnet cores. Very seldom made of sheet iron, sometimes of wrought iron forgings, but generally are steel castings.

Fig. 199 shows a field coil and a magnet core of an alternator. The winding of copper ribbon wound edgewise. The pole piece is almost same size as coil.

Fig. 200 shows a shunt and series coil (large one is shunt coil) wound and taped ready to be shipped on the magnet core.

Fig. 199. Field Coil of Ribbon wound edgewise, with Laminated Magnet Core (on left).

This core has the pole piece cast with a hole, which is bored to a driving fit on the core.

Fig. 200. Shunt and Series Coils ready to put on Core.

Fig. 201 shows a ring yoke with the field coils in place. Fig. 202 shows one of these fields ready to be bolted in place.

Bearings. Should be large; four to six times as long as the diameter of the shaft they contain; on account of the high speed. They are usually of the self-oiling type.

If there are collars on the shaft they should be arranged to allow the shaft to *float,* i. e., to move to and fro about 1-16 to 1-8 of an inch so as to distribute the

Fig. 201. Ring Yoke with Field Coils in place.

oil in the bearings and to wear the commutator evenly. If there were no float, the brushes always touching on the same line around the commutator would wear grooves in the bars.

Rotary converters will not float of their own accord, so a magnetic or mechanical device is installed at one end of the shaft to compel a regular and even float.

At other end of shaft is often installed an "over speed" device to shut down power in case rotary "races."

Shafts are made thicker under the armature core than in the bearings; for the stress is greater out between the bearings, since the load acts with a lever arm.

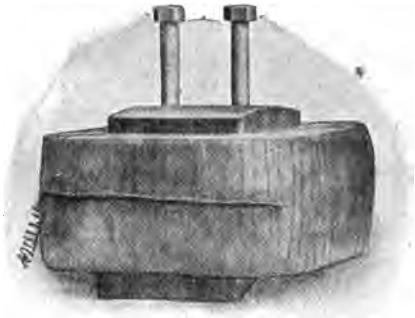


Fig. 202. Field Coil of Fig. 201 ready to be bolted into place.

They are made larger than in ordinary machinery because there is frequently a magnetic side pull due to unequal strength of the field magnets or the polar bore being eccentric with the shaft.

It is almost impossible to pull an armature out of the fields while current is passing through the field coils.

Core. The sheet iron body upon which the armature winding is placed.

Fig. 203 shows a toothed core into whose slots the armature winding is laid. The core is held firmly between two end plates, by bolts passing through tubes of insulation (usually fibre).

Generally the armature core is held by a *spider,* whose hub is turned and keywayed to receive the commutator hub. The spider hub is also bored, reamed and keywayed so as to form a *sleeve* or *quill,* which is slipped on the main shaft. In this case the complete armature may be removed for repairs without disturbing the commutator leads or getting core and commutator out of alignment.

Fig. 203. Armature Spider and Toothed Core.

Fig. 203 shows this construction.

Hysteresis. When the iron core revolves it passes in succession under N and S poles and so the magnetism of the core is reversed.

All iron, no matter how soft, holds some *residual magnetism.* This "hanging on" of the magnetism is called *hysteresis.*

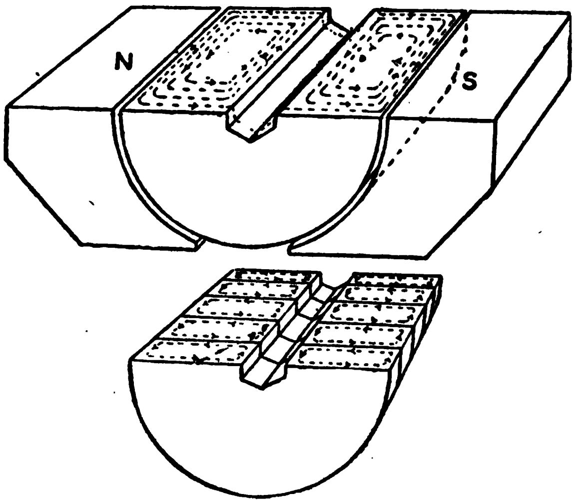


Fig. 204. Effect of Solid and Sheet Iron Construction on Eddy Currents.

Before the magnetism in the core can be reversed the residual magnetism must be wiped out. It takes about 1½ per cent. of the total power of a generator to do this work. This inevitable loss is made as low as possible by the use of a small quantity of the softest iron, worked at a low magnetic density. Increasing the quan-

tity of magnetism per square inch, the speed of the machine or the pounds of iron in the core *all* increase the loss due to hysteresis.

Eddy currents, sometimes called Foucault currents. There must be E M F induced in the iron of the core, just the same as in the copper on the core. Were it not that the core is in sheets placed parallel to the flux, there would be a great waste of power sending current

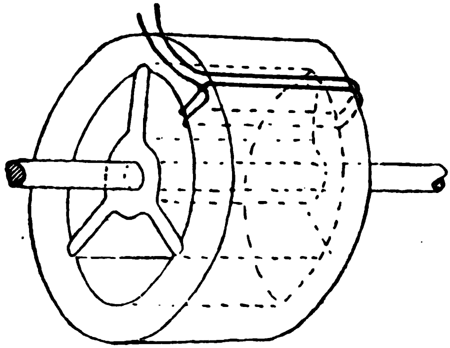


Fig. 205. Ring Winding.

through a short thick body of iron. (Hence of low resistance.) The insulation of rust, etc., between the sheets forms a series of short, very thin conductors which are of high resistance, and hence the eddy currents are small. An increase of speed makes a great increase in the eddy currents. The usual loss due to them is about 1½ per cent. of the total power generated.

Fig. 204 shows how the paths for eddy currents are made long and narrow by using sheet iron.

ARMATURE WINDINGS.

Ring. These windings are very simple to calculate but hard to place on the core. The method of winding is shown in Fig. 205.

Fig. 206. Formed Armature Coil.

Drum. The double cotton covered wires are bent into shape, insulated with linen tape, baked and shellac varnished. A number of these *formed coils* (Fig. 206) are placed in the slots (Fig. 203) on the outer surface of the core (Fig. 207, also Fig. 208) and their ends soldered to the commutator bar lugs (Fig. 209).

Each slot contains two inductors. One side of a coil is in the bottom of a slot under a N-pole, and the other side in the top of a slot under a S-pole. This same slot has in its bottom a second coil, the outer side of which is in the top of a slot under a N-pole. The first men-

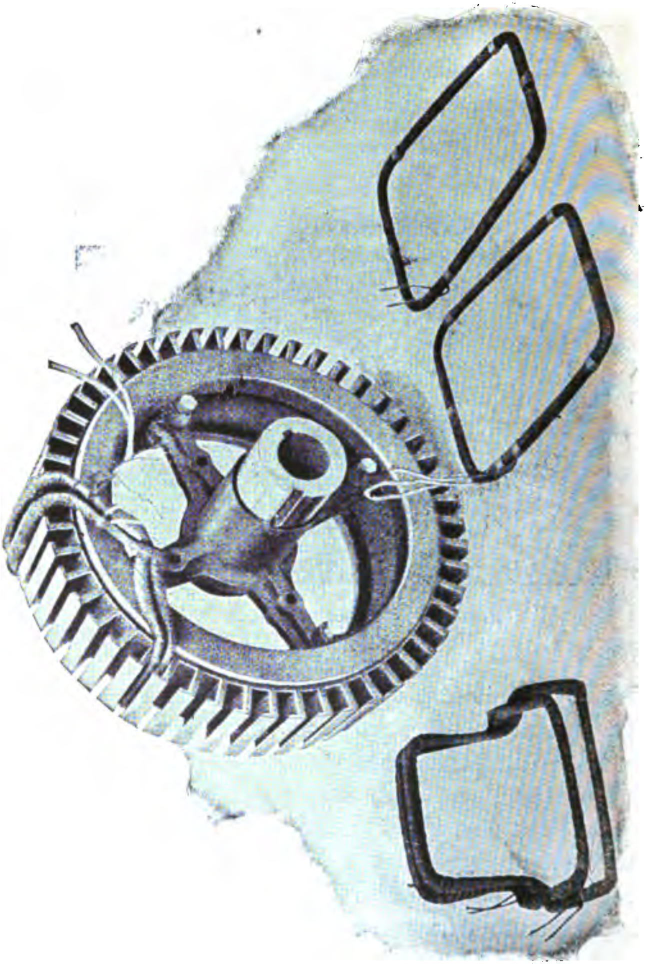


Fig. 207. Toothed Core with Formed Coil Winding.

tioned coil has its two ends connected to any two adjacent commutator bars, and the second coil is connected in the same manner to two bars on opposite side of commutator.

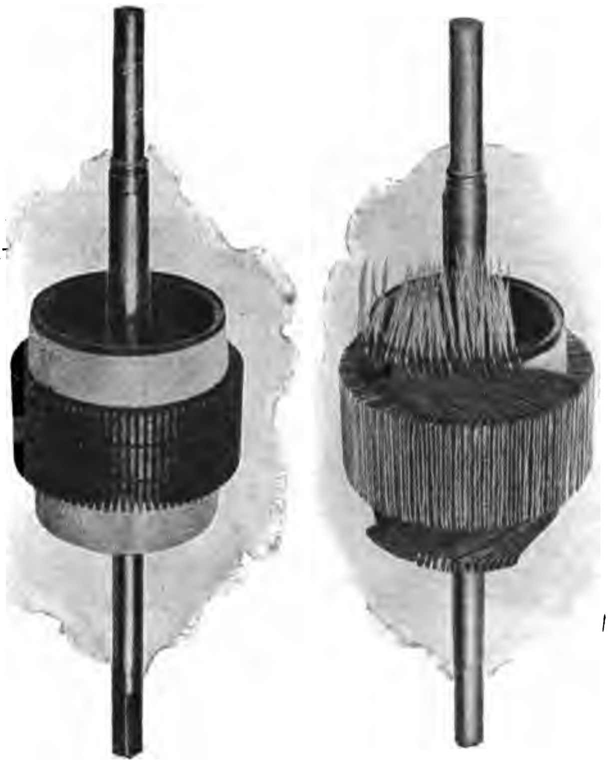


Fig. 208. Formed Coil Winding Incomplete and Completed.

Commutators. The peculiar shape of the bar (Fig. 210) makes it possible by the corresponding shape of the hub and washer to draw bar and insulation (mica)

together tightly, both side, endwise and downwards, locking them absolutely in place by a nut bearing against the washer.

The hub is sometimes keyed to the shaft. This gives a chance to remove the commutator for repairs by unsoldering the leads from armature winding.

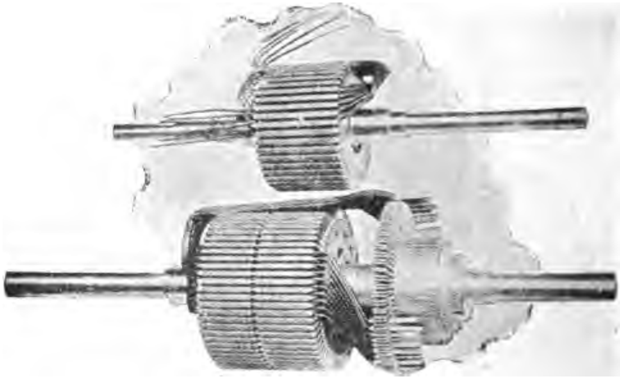


Fig. 209. Armature Winding connected to Commutator.

A complete armature, i. e., wound core and commutator, is shown in Fig. 211 on a quill ready to be put on axle or shaft.

The golden copper color of a new commutator soon changes to a uniformly rich dark mahogany brown, and its surface acquires a polish. The degree of the polish and uniformity of the color are indications of the success of operation. Any blackening of the bars or roughness of surface shows defects in machine or manner of operating.

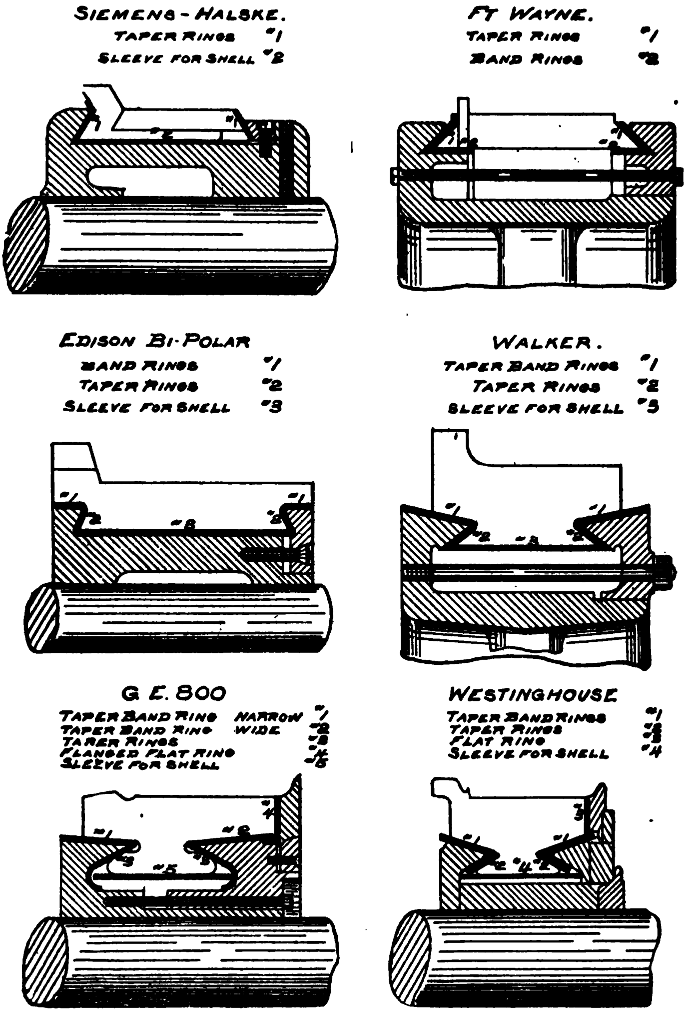


Fig. 210. Construction of Commutators Showing Hub, Mica and Bar.

Brushes of *copper* or brass in the form of sheets or folded gauze were formerly much used. In the modern machines with the losses reduced by clever designing, more current is drawn, a higher voltage generated and larger pole pieces used on the same sized armature.

The tendency of the brushes to spark is thereby increased and to offset this *high resistance* brushes must be used. Hence the use of carbon brushes is universal. Where the tendency to spark is not so great graphite brushes are used.

Fig. 211. Complete Armature.

For mechanical reasons copper rubbing on copper wears worse than carbon on copper. The abrasion between two surfaces of same material is generally worse than two different ones.

Dynamo brushes sometimes set at a slight angle from being perpendicular to the commutator as they always revolve in same direction.

For a motor the brushes are set radially against the commutator, for otherwise it could not be reversed with-

out danger of breaking the brushes. They are pressed against the bars at about 1¼ lb. per square inch.

Sufficient area of carbon must be actually touching the commutator to collect the current at a density of 30 to 40 amperes per square inch.

This total area is divided up into small blocks about 1½x2 or 3 inches, and each has its own spring. This insures that at all times all of the brush surface is in contact with the commutator.

Fig. 212. Brush Holder.

Brush holders. The holders must clamp the brushes securely and press them straight against the commutator, as in Fig. 212. There must be sufficient area of contact between holder and brush, with good pressure so that the current may pass from brush to holder without producing a great C R loss.

The springs maintaining the pressure of the brush against the bars should not carry current, as they might heat and have their elasticity destroyed.

The current carrying capacity of the brush holders is often supplemented by *stranded* or *braided* conductors

of copper, running from the brushes back to the brush holder cables. These are called "pigtails."

A set of brush holders is mounted on a brush holder arm or stud.

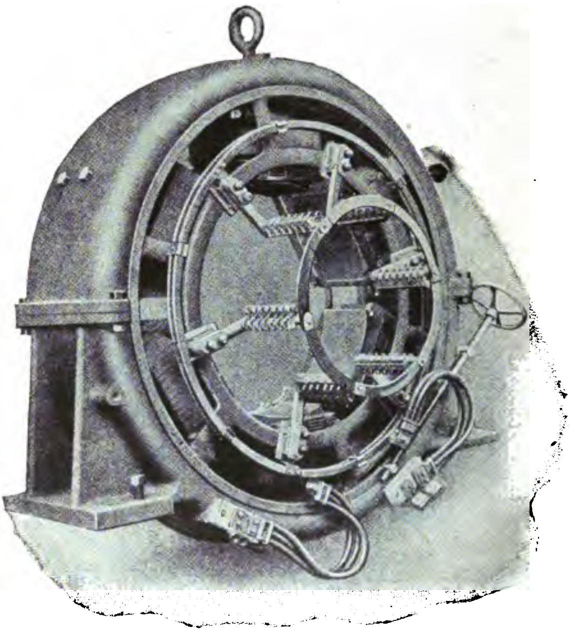


Fig. 213. Complete Brush Rigging on a D. C. Generator.

The brush holders on opposite sides of the commutator are not in the same plane, but by having one stud a little shorter than the other the brushes are *staggered*. There is then no part of the commutator not worn by the brushes, and this together with the *float* of the shaft, keeps the commutator a perfectly smooth cylinder of slowly decreasing diameter as it wears.

An oval, barrel or spool-shaped commutator due to improper wear must be swung in a lathe and light cuts taken until it is again of the correct shape. This is called *turning down.*

The brush holder studs project from a ring which slides in grooved arms supported by the bearing pedestal or by the field frame. They can thus be moved simultaneously and set into the position of *no* or minimum sparking for full load, then locked in place. See Fig. 213.

Fig. 214. Brush Holder on R. R. Motor.

On *railway motors* each holder stud is often clamped temporarily to the field frame or transoms of truck until the correct position is obtained, when they are bolted permanently directly against frame or transom.

The ability to change their position simultaneously is thus lost, but simplicity and reduction of number of parts and weight is obtained.

Figs. 214 and 215 show brush holders of railway motors.

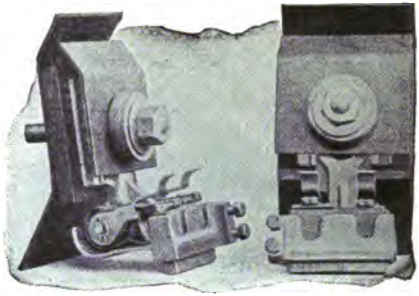


Fig. 215. Brush Holder on a R. R. Motor.

Fig. 216. Set of Brush Holders and Collecting Cables.

In Fig. 216 is shown an arrangement similar to Fig. 213. It is for a smaller dynamo and has no hand wheel to set brushes, but merely a set screw clamp shown on left side.

Field coils. The spools in which these coils are wound are made of brass or bronze, which being non-magnetic does not cause any leakage through its flanges.

Copper *strip* or *ribbon* is used on railway motors and fuller board or card board insulation between turns. Fig. 199.

To prevent injury to the windings they are usually wound with a layer of cord or tape. Fig. 217.

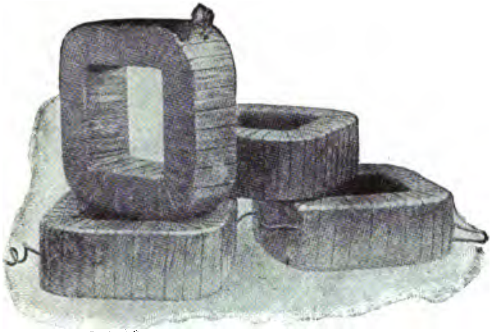


Fig. 217. Field Coils taped ready to place on Magnet Cores.

Fig. 218 is a railway motor field coil wound of strip copper and protected by a layer of cord. In motors where the field frame is not a shell completely enclosing the fields and armature protection is furnished to the coils by brass shells. These are riveted to the flanges of the field spool.

In the New York Central locomotive two hand holes are left, one containing the two terminals of the coil. Into these holes are poured a hot bituminous insulating compound, and when cool the covers are screwed on.

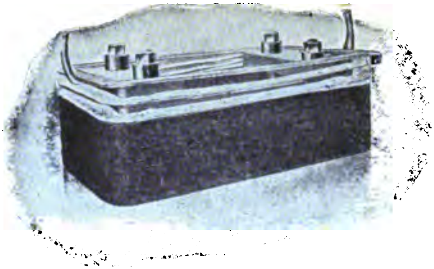


Fig. 218. Field Coil Wound with Strip Copper Insulated with Asbestos.

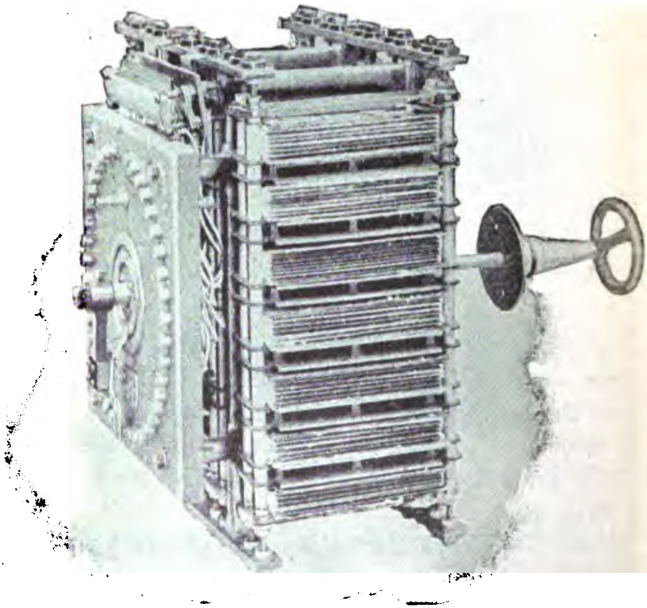


Fig. 219. Field Rheostat for Railway Generator.

From transom to transom under the armature is hung a curved piece of brass to protect it from flying stones and pieces of iron. Being perforated with 5-16 holes it does not interfere with the passage of air to cool the armature.

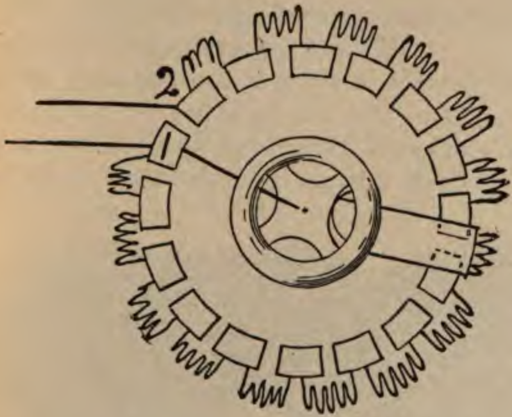


Fig. 220. Diagram of Field Rheostat.

Rheostat. In a dynamo an extra resistance, the value of which is about 25 per cent. of that of the fields, is placed in series with them, and by cutting more or less of this *field rheostat* in or out of the circuit, the field current is strengthened and weakened and the voltage of the generator increased or diminished.

At least part of this resistance is always in circuit and it is so designed as to size of wire and ventilation as to do this and not overheat.

Fig 219 shows a rheostat for a railway generator.

The handle projects through the switchboard, while the resistances made of cast iron are behind the panel. In Fig. 220 is shown the operation of such a rheostat. The current enters at 1 and goes through half of the resistance and out at 2. The amount of resistance in circuit being thus regulated by position of handle.

LESSON 27.

Railway Motors.

The main difference between ordinary and railway motors is compactness and inclosure.

The space that can be given to a motor on a truck is limited by the gauge of the rails and the size of the wheels. The gauge being fixed makes this dimension of the motor absolutely fixed; so that more room can only

Fig. 221. D. C. Railway Motor, 40 H. P.

be obtained by using larger wheels. A 36 inch wheel gives none too much room to instal motors which are to be called on at times to give 200 H. P. The usual car wheel is 33 inches in diameter.

A railway motor must be completely inclosed to protect it from dust and flying stones.

Figs. 221 and 222 show inclosure of the motor and the gear case. The cast steel box which protects the motor also serves as the field yoke.

This motor has an armature 14 inches in diameter, the commutator is 10¼ inches in diameter and is composed of 111 bars. Motor with gears and gear case weighs 2730 pounds.

Fig. 222. Gear Case end of D. C. Railway Motor, 40 H. P.

The motor in Figs. 223 and 224 is a 60 H. P. motor built for A. C. work. The armature is 16 inches in diameter and commutator 12 inches in diameter, having 117 bars.

As shown it weighs 4000 lbs. and the gears and gear case weigh 500 lbs. more.

When mounted on 33 inch wheels there is 4⅜ inches clearance between bottom of motor and top of rail.

On account of the almost complete inclosure the armature must be designed to ventilate itself as much as is possible.

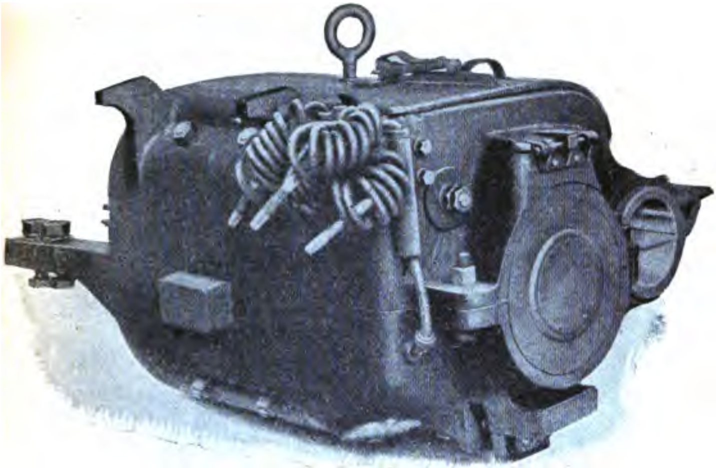


Fig. 223. Commutator end of A. C. Railway Motor, 60 H. P.

Fig. 224. Pinion end of Fig. 223.

The air is usually drawn in at the rear end (Fig. 225) and forced through windings and core by the shape of the spider, being discharged between commutator leads and against the pole pieces.

The case of a railway motor is usually split so that the lower half swings down or in a few instances the upper part of case can be swung up.

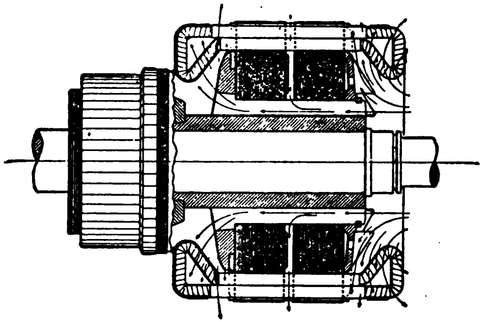


Fig. 225. Method of Ventilating Armature.

Fig. 226 shows the 40 H. P. motor of Fig. 221 with lower part of case down. By loosening the bearing bolts the armature can now be lowered into the pit and removed.

The pole piece and its field coil surrounding it are shown in the upper half of case.

The 60 H. P. motor of Fig. 223 is shown with upper part of case removed in Fig. 227. This is a four pole motor, two of them showing in the part removed. The brush holders also show in top part of upper case.

The four pole pieces are built up of soft steel punchings, riveted together between end plates of wrought iron and are held to the motor frame by bolts. The poles project radially inward at angles of 45° with the

Fig. 226. Lower part of Case let down. Same motor as Fig. 221.

horizontal. Two bolts, secured by lock washers, hold each pole piece in place. They do not penetrate the pole face but terminate in heavy rivets inside the pole made for this purpose. A smooth and unbroken pole face is thus presented to the armature.

The poles are made with projecting tips, which properly distribute the magnetic field, and also serve to retain the field coils, which are held firmly in place by spring washers. The coils are wound with asbestos-covered wire. They are heavily taped and are treated with specially-prepared insulating compounds which render them practically moisture proof.

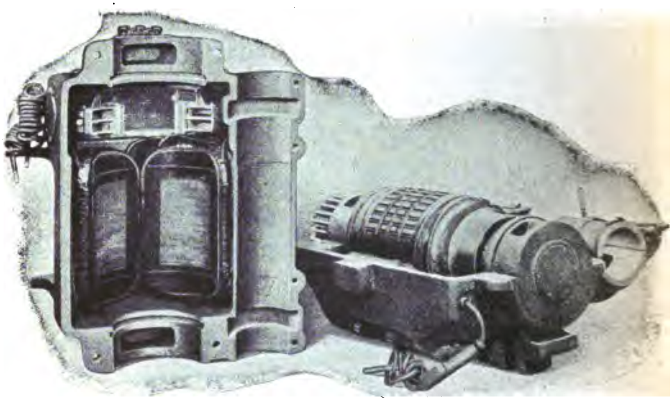


Fig. 227. Upper part of Case on Motor shown in Fig. 223 taken off.

Fig. 228 shows a 50 H. P. motor for A. C. with upper part of case raised.

There is in railway use to-day in this country practically only one motor, the series motor. This is used or D. C. or A. C. with very little difference in construction.

The armature winding for A. C. use being slightly different, for a separate winding is connected to the commutator bars called a preventive winding which prevents sparking.

In Europe the induction motor supplied with polyphase current is used considerably. The necessity for two or three line wires and double or triple trolleys, while not so very objectionable, has prevented its use in this country.

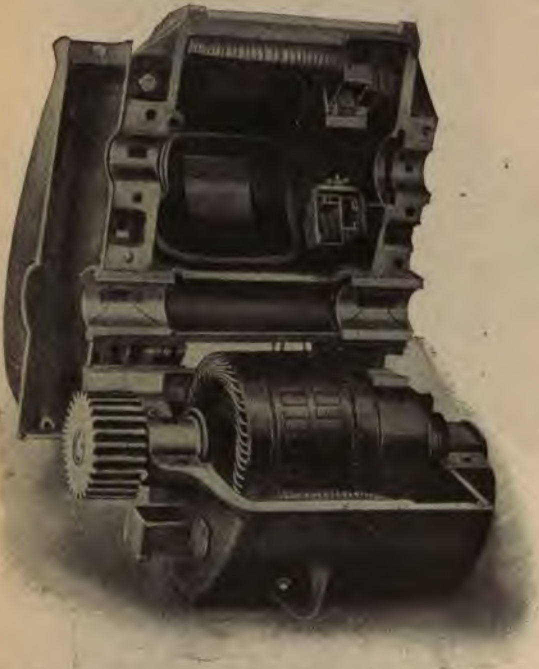


Fig. 228. Upper part of Case Raised on 50 H. P. A. C. Motor.

Box Frame Type of Motor. The rapid development of inter-urban railways created a demand for a motor of large capacity, which could be mounted under a car in a limited space. To meet this contingency was devel-

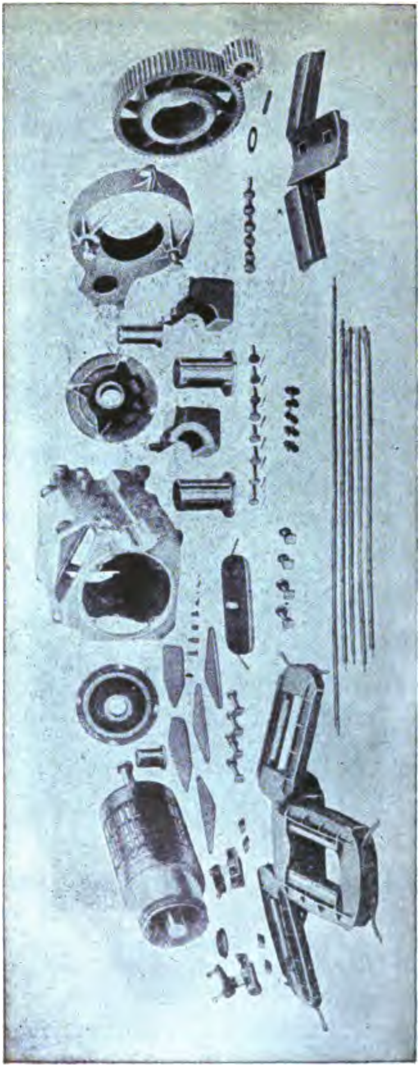


Fig. 229. Parts of a Box Frame Motor.

oped the box frame type of railway motor. This type of motor differs from the ordinary split frame motor, in that the magnet frame consists of a one-piece hollow casting, open at both ends. The armature is inserted in position from the side, being retained in place by end plates, which fasten to the field frame. One of the advantages of the box frame motor is the continuous mag-

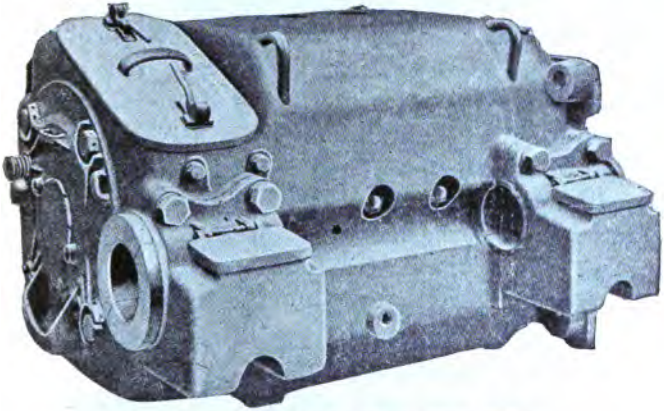


Fig. 230. 125 H. P. Box Frame Motor.

netic circuit which exists throughout the frame. Additional advantages consist of a long commutator, ample room for ventilation, and absence of leakage of oil and water into the motor body. The armature may be removed from the motor frame at one side, obviating the necessity of employing a pit. Fig. 229 illustrates the various parts of the box frame type of motor ready for assembling. Fig. 230 shows a 125 H. P. motor of the box type.

The Series Motor.

The series motor is a motor in which the same current goes through field and armature. It is usually a four pole motor only two of which have field coils, the other two being magnets because they are a part of the magnetic circuit. The poles are short and the coils broad and flat. The armatures are drum wound. When used on D. C. the magnet cores may be solid metal, but for A. C. they must be of sheet iron, as is also the *yoke*.

The only difficulty in operating such a series motor on A. C. circuits is the sparking. This is prevented by a resistance placed between each commutator bar and the one next to it, and lowering the voltage applied.

These resistances are wound in the armature slots and are called the preventive winding.

However, to make the motor operate with good efficiency on A. C. the field coils are actually imbedded in the iron of the magnet core, and the armature is made about 10% greater in diameter, revolving also at a greater number of revolutions per minute.

Such a motor takes only 250 volts A. C. against 500 volts D. C. It is larger and heavier than its mate designed to run on D. C.

If you will notice the air gap between pole pieces and armature it is less on the A. C. motor.

The D. C. series motor can exert a greater H. P. to start a train than the A. C. series motor; and the D. C. motor will get the train up to full speed quicker than the A. C.

It is a peculiar thing that all additions to the D. C. series motor in order to make it equally good as an A. C. motor also make it a better D. C. motor.

If a 200 H. P. motor giving 80% efficiency at 500 volts increased in size and weight by the additions and then run on 300 volts A. C. it will develop nearly 200 H. P., but if put back on D. C. again it will develop 275 H. P.

The fact is that a cheap, light D. C. series motor develops the same horse power as a more expensive heavier A. C. series motor.

Further an A. C. and D. C. motor of the same size and weight operate respectively on 225 and 550 volts and give 125 and 240 horse power.

The Induction Motor.

It has been known for a long time that there was a strong repulsion between the coils of a transformer, so that it was hardly a novelty when a transformer was made with the secondary built on the inside of a ring yoke and the primary on the outside of an armature core.

This transformer acted like a motor—in fact it was a motor. In order to give the motor good starting power it was wound for and served with three phase currents, and a resistance wound in with the primary so arranged as to be cut out after machine was up to speed.

The names armature and field will hardly apply to such a motor, so that the names Stator and Rotor have been adopted.

The Stator is the stationary winding whether connected to outside power or not.

The Rotor is the rotating part.

As usually built the stator consists of a winding producing a large number of poles, six and upwards, for the more poles the slower the rate of speed. The induction

motor having an inherent tendency to revolve at tremendous speeds according to formula,

Velocity in rev. per min. $= 60 \times$ frequency $\div$ number of pairs of poles,

it will be seen that many poles and low frequency are necessities.

The stator being served with two or three phase currents each pole is caused by the action of two or three coils. As the current rises and falls in these coils the magnetism grows and fades away. Hence the point of the stator where magnetism is greatest is continually moving around the stator.

Hence we say that it is a revolving field.

The stator winding is continuous and has no connection with rotor or outside power. The current in it is induced by the transformer actions of the rotor.

The rotor is usually a slotted core of sheet iron in each of which is part of a single conductor coil. These coils are all connected together at one end and in groups of two or three; are connected to slip rings through which current is carried to the rotor windings.

Sometimes the ends of the windings project out of the slots and have German silver pieces attached to them, a ring being arranged to slide along the German silver pieces. To start motor the ring is slid out so that the winding has a high resistance. When up to speed the ring is slid in and cuts out the resistance, leaving only the regular winding in circuit.

For railway work the coils are usually connected directly to the slip rings and the resistances inserted in the lead going to the brush. Care must be taken to have

these resistances exactly equal and to have them reduced simultaneously until cut out altogether.

These motors are doing excellent work in Europe, but to an American the induction motor equipped locomotive or car seems a huge joke.

In the first place an induction motor runs at one speed and only one speed. After train is started it runs at 20, 30 or 40 miles per hour as steady as a clock, up hills, down hills.

In order to get different speeds four motors are often used, all being used at low speeds and only two of them for high speeds. This is so because if the current from one stator is fed into next rotor, the result is the same as if one motor of many poles was being used and the speed is slow, when each motor is being worked independently the result is same as one motor of few poles and the speed is high.

In certain cases two motors having a different number of poles are used. For slow speed, the rotor of one feeds stator of second. For next highest speed the motor with larger number of poles is used alone; and for highest speed the motor with fewest poles is used alone.

Induction motors have the peculiar property on down grades of feeding power back into the trolley and thus assisting the power house to run other trains up the hills.

Relation of Flux in Armature and Field of Motor.

It has caused much surprise to the unthinking that a series motor should continue to revolve when switched from D. C. to A. C.

Consider the diagram in Fig. 231. Suppose the current

to flow so that the field polarities are as marked. The armature polarities will be such that near the upper brush is a N-pole and near the under brush a S-pole, these poles being directly opposite each other. The top pole of armature being N, the N-field magnet will push and the S-field magnet pull, so that armature will begin to rotate in clock-wise direction.

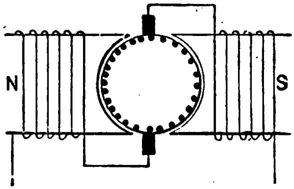


Fig. 231. Diagram of Circuits in Series Motor.

Suddenly reverse the current. All the polarities will change, but motor will continue to revolve in same direction.

The left magnet is now S, the top of armature S, and the right field magnet is N; hence the push and pull of fields on armature is same as before. Hence a series motor will run on A. C. circuits, for while the polarities keep changing the turning effort or torque is always exerted in some direction.

Reversing a Motor. To reverse the direction of a motor, you must change the direction of the current through the fields or through the armature, but not through both. Interchanging the two main leads to a motor will not affect its direction of rotation. Remember that reversing the current reverses the polarity.

Direction of Rotation of a Motor. In Figs. 232, 233 and 234, A represents the armature core and S. N. the pole faces. The windings of armature and fields are indicated by circles, being marked + when current flows toward observer, and — when it flows away from him. The blank circles carry no current.

In Fig. 232 the flux is due to the field coils alone and the polarity is indicated by the letters S. and N.

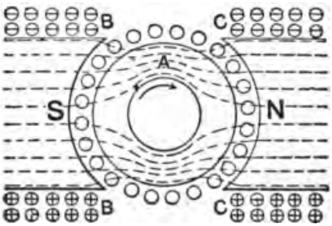


Fig. 232. Field Flux Alone.

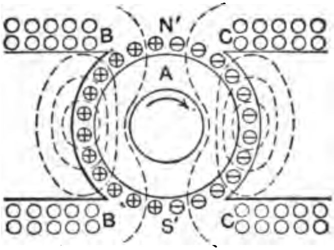


Fig. 233. Armature Flux Alone.

In Fig. 233 we have the flux due to the armature current alone, when the machine is driven as a generator in direction as shown by arrow, producing poles at N′ and S′.

Instead of letting the machine supply electricity, furnish current to it; flowing through armature and fields at the same time and in the same direction as before. The polarities will remain unchanged and the armature will begin to revolve as *a series motor, in the opposite direction to that in which it was driven as a series dynamo.*

A shunt motor will rotate in same direction as a motor or as a generator because when current is supplied to terminals of machine it runs through field in same direc-

tion as before, but through armature in opposite direction. Refer to Fig. 196.

Sparkless Reversing. The conditions when current flows through an ordinary series motor ready to operate in a direction opposite to the indication of the arrow are shown in Fig. 234.

The brushes are, of course, at N′ and S′ but since they should be in a line at a right angle to the general direction of the flux, it is evident that they are ***not*** at the place for sparkless operation.

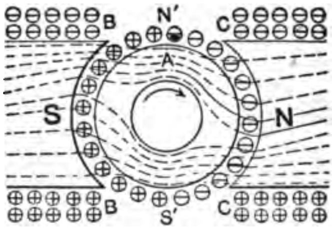


Fig. 234. Combined Field and Armature Fluxes.

The magnetic flux takes the peculiar direction shown in Fig. 234 due to the interaction of the field and armature fluxes.

Looking back at Figs. 134 and 135 you will see that it is natural that when these fluxes occur at the same time, the N′ would attract the S flux, and the S′ pull the N flux so that the resultant or machine flux would be as in Fig. 234.

The stronger the armature flux and the weaker the field flux the more the machine flux is twisted.

If the armature is weak and the field very strong the effect of the armature will be very slight, or as we say "the *armature reaction* is small," and the machine flux will look like Fig. 232.

In this case the brushes at N′ and S′ are in the proper place for sparkless operation.

If the flux were like Fig. 234 upon reversal of the armature current the flux would twist in the other direction, but if the flux were like Fig. 232 the reversal has no effect.

The machine flux of all railroad motors is like Fig. 232, so that they may be reversed without any change of brushes.

LESSON 28.

ALTERNATORS.

The main difference already noticed between the D. C. generator and the A. C. generator, called for shortness' sake an alternator, is that one has a commutator and the other a collector.

There are, however, differences in construction which must be noticed.

The highest voltage for which D. C. generators are wound is 1200, this being the lowest voltage for which alternators are wound, while for railroad work 11000 is the usual and 22000 not uncommon.

This makes the problem of proper insulation for A. C. armatures more difficult. To make the work easier, instead of having the field stationary and armature revolve as in most D. C. generators, in alternators the field revolves and the armature is stationary.

The field is fed with D. C. at 250 volts pressure and is easy to insulate even though subjected to the mechanical strains of rapid motion and the lack of plenty of space.

The armature being stationary there are no mechanical strains, also weight being no objection plenty of space can be given to insulation.

This type of construction is shown in Fig. 235 and 236. Fig. 235 shows a revolving field of 18 pairs of poles or 36 poles. Current is led in through a collector. This field revolves inside of the stationary armature (Fig. 236) whose windings are fully exposed to the cooling effect of

the air. This armature needs no collector, for the terminals of the winding are attached to leads which come out of the base at one side. (In the Fig. at right side.)

Ventilation of the field and armature is accomplished by means of air ducts as is well shown in Fig. 237.

Fig. 235. Revolving Field of Alternator.

The magnetism in all armatures fluctuates and reverses in polarity as it passes or is passed by the poles; but in alternators these reversals of magnetic polarity are much more rapid than in D. C. machines.

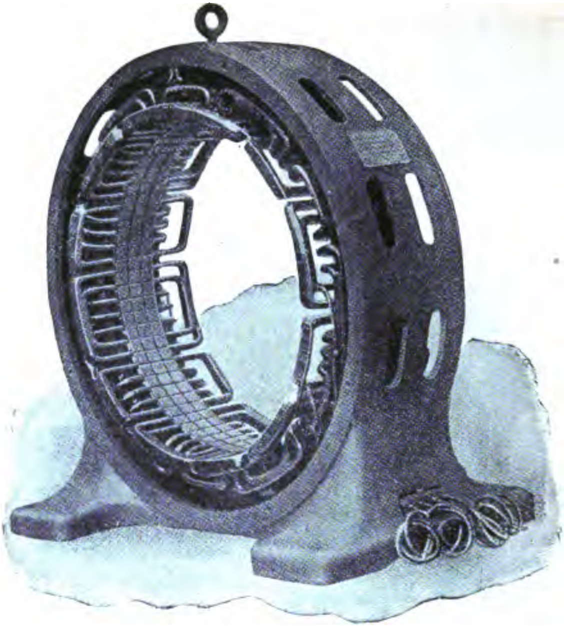


Fig. 236. Stationary Armature of Alternator.

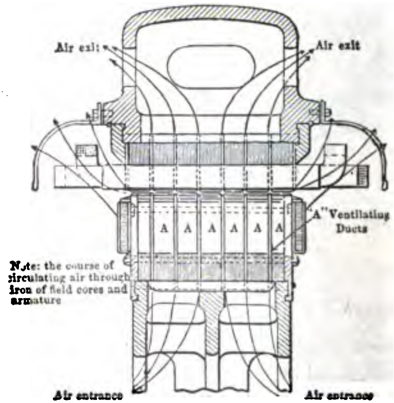


Fig. 237. Method of Ventilating Alternator with Revolving Field and Stationary Armature.

To prevent the waste of power necessary to magnetize and demagnetize solid iron at such a rapid rate, not only is the armature iron laminated but the magnet cores also.

Fig. 238 shows such a magnet core and Fig. 239 shows the way these cores are attached to the magnet frame or yoke.

Fig. 238. Pole Piece and Core of Laminated Construction.

The Exciter.

To furnish the field current for all the alternators of a station two small D. C. generators are used, one being run while the other is being cleaned or held in reserve.

When storage batteries are in station it is often the custom to make each exciter of such a size as to carry continuously three-quarters of the field load.

When station is fully loaded, *i. e.* all alternators running, both exciters are run, and when load on station is light one exciter is shut down. In cases of exciter trouble the storage battery furnishes the field current.

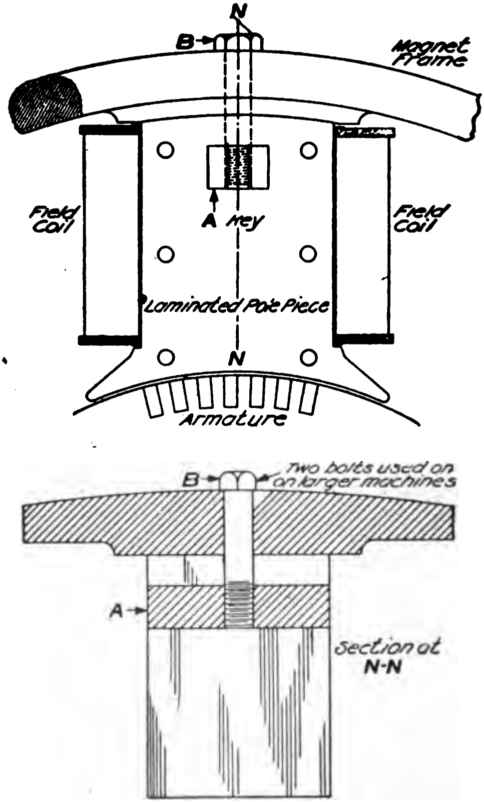


Fig. 239. Attaching Cores to Yoke.

Single Phase.

The field coils occupy about 50% of the surface of the field bore, because when their inner edges are tight together their outer edges are apart due to the larger circumference at the pole pieces, and because some inter-

polar space must be left to prevent excessive leakage from pole to pole.

Only 50% of the armature bore is wound, for otherwise the coils would be so wide that they would extend over into the field of a wrong pole piece. If one side of a coil is under a N-pole the other side should be under a S-pole. Then the two E. M. F.'s induced add together. Should the coil be so wide as to extend over to the next N-pole any E. M. F. induced by that pole would be subtracted.

There is then on the ordinary alternator half of the armature empty. Such a machine is called a Single Phase Alternator.

It occurred to some inventor that an entirely separate winding could be put on between the coils of the original winding and be connected to its own collector. The current was to be led to a different circuit, but it soon became evident that it was better to make of the four wires from the alternator a three-wire circuit by joining two of them inside the armature and leading out three wires to the switch board. Such an alternator is a Two Phase Alternator.

Of course the capacity of the machine is not doubled, because from a single phase alternator is drawn enough current to heat it to the safe limit. From a two phase alternator we do the same thing. The reason we gain in capacity is because in a single phase machine the heating is concentrated, while in the two phase machine it is evenly distributed all over the armature.

Even in a two phase alternator there is a portion of the armature not used for winding and there was still a desire to reduce the number of line wires. This led to the Three Phase Alternator.

The three armature windings of the alternator are connected together at one point and the other ends to the three collector rings or the three windings are connected in series and the three points where they are joined are connected to the three collector rings.

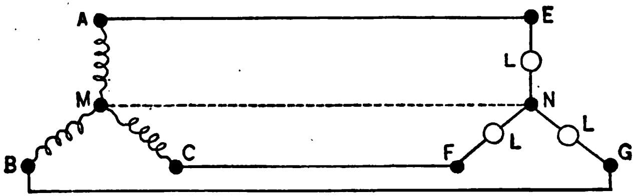


Fig. 239a. 3 Phase Y Connection.

The former winding is called a Y winding and is shown in Fig. 239a. The latter is a Δ (Delta) winding and is shown in Fig. 239b. The European names are respectively Star and Mesh windings.

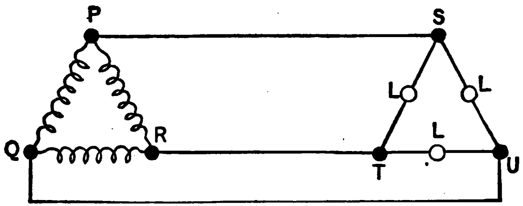


Fig. 239b. 3 Phase Delta Connection.

The three wires of a three phase system each act as a main wire and a return wire for one of the others at the same time. The actual current in the wire is the difference of the two currents: in and outgoing.

If the same three phase armature is connected first as a Y and then as a Δ winding these differences will be noticed.

The Y armature will give the higher voltage and have less current capacity. The Δ will give a lower voltage and have greater current capacity. Power that can be drawn from each is the same.

Transformers and other apparatus are wound two and three phase, and also Y and Δ for use with the correspondingly wound alternator.

By a peculiar connection of coils rotary converters are wound for six phase currents; it having been discovered that it is possible to do so with the result of increased output for a given sized machine.

Two, three and six phase machinery is often grouped under name of polyphase.

LESSON 29.

CATECHISM ON DYNAMOS,* MOTORS.†

The very brief answers given here may be added to by reference to the Lessons just studied.

Question 1. How is output of dynamo stated?

Answer. In Kilowatts equal to 1000×volts×amperes.

Question 2. How is output of motor stated?

Answer. In horse power, equal to Watts intake÷746, ×efficiency expressed decimally. (Not as a percentage.)

Question 3. What is voltage of a dynamo? of motor?

Answer. It is the pressure the generator or alternator delivers at its own terminals. The voltage of motor is the voltage which should be applied to its terminals in order to develop full horse power.

Question 4. What is full load current of dynamo? of motor?

Answer. Full load current of a dynamo is that current which may be drawn steady for 24 hours without causing any part of machine to exceed a safe temperature, *i. e.* 150° Fah. This applies to factory motors.

Of a railway motor it is the current which passing through motor for one hour as it runs on the blocks in testing room, will cause it to rise to a temperature of 212° Fah. We mean, of course, that the hottest part shall be no hotter than 212° Fah.

*Includes all machines generating electricity, D.C. or A.C.

†Includes all machines utilizing electricity, D.C. or A.C.

Question 5. What is meant by the rating of a dynamo? Of a motor?

Answer. The product of full load current multiplied by the voltage expressed in Kilowatts is rating of a dynamo. The actual mechanical horse power developed at the pinion of the motor as tested in shop. The gearing increases the power applied to and reduces the speed of the car wheels.

Question 6. What is armature core?

Answer. The sheet iron body which carries the armature winding and conducts the flux from pole piece to pole piece.

Question 7. What is armature spider?

Answer. The casting consisting of hub and arms which supports armature core.

Question 8. What are binding wires?

Answer. They are narrow bands of phosphor bronze wire placed around armature every three or four inches to help bind winding to core. They rest on strips of mica and are sweated with solder all around.

Question 9. What are commutator segments?

Answer. The commutator segments or bars are the copper pieces of which the commutator is built.

Question 10. What are commutator leads?

Answer. They are the ends of the armature winding extending from core to the lug of the commutator bar.

Question 11. What are pole pieces?

Answer. The end of magnet core nearest the armature. Usually larger than core.

Question 12. What are magnet cores?

Answer. The iron inside the field coil.

Question 13. What is the yoke?

Answer. The part of magnetic circuit connecting the magnet cores.

Question 14. What is the pitch of an armature winding?

Answer. It is the number of teeth between the two sides of a formed coil plus one tooth.

Example: The two sides of a coil are in slots number 3 and 17, then pitch is 14.

Question 15. Is there insulation between winding and core?

Answer. Yes. Mica or fuller board; there is also the tape on coil.

Question 16. What insulation is there between conductors of winding?

Answer. The double cotton covering of each wire makes four thicknesses between conductors.

Question 17. What is the air gap?

Answer. It is the air space between armature and pole pieces. In dynamos it is made as small as possible for efficiency.

In motors it is not made too small because this tends to make machine spark due to the weak field. In D. C. series motors it is from 1/8 to 1/4 of an inch, in A. C. series motor it is smaller, say 1/10 to 1/8 inch.

The larger the air gap of a motor the more the bearings may wear before there is danger of armature rubbing against lower pole pieces.

Question 18. What are field spools?

Answer. The brass shells on which the field coils are wound.

Question 19. What is the commutator?

Answer. It is a series of copper bars placed parallel to shaft, insulated from each other and from the frame of machine. Each is connected to the winding and current flows from winding through them to brushes. It at the same time reverses the connections between the brushes and winding at the proper times so that the brush always collects current.

Question 20. What is a collector or slip rings?

Answer. A collector consists of two or more rings of copper placed around the shaft and insulated from it and each other. Each is connected to a part of the winding. The brushes rest on the rings.

They are used to collect current from a revolving armature style of alternator, to feed current into armatures of rotary converters or the revolving fields of alternators.

The collector has no corrective influence and passes on the A. C. or D. C. current exactly as it receives it.

Single phase machines have two rings; two, three and six phase machines have three rings.

Question 21. Is there a difference between no load and full load voltage of dynamos?

Answer. Yes. A shunt dynamo gives highest voltage at no load and lowest at overloads; the series dynamo gives lowest at no load and highest at full load. The compound dynamo is a combination of series and shunt and gives some voltage at all loads. Fig. 240 will make this clear.

An alternator acts like a shunt dynamo.

Question 22. What is a field rheostat?

Answer. It is a resistance in the field circuit which

can be varied to change the current, and hence the field strength. This alters the voltage of dynamo.

Question 23. What are commutated fields?

Answer. In some motors the field coils are arranged in sections so that they may be arranged in parallel or series, or in combinations.

All coils in parallel give the greatest current and hence slowest speed of motor; all coils in series give the weakest field and the fastest speed.

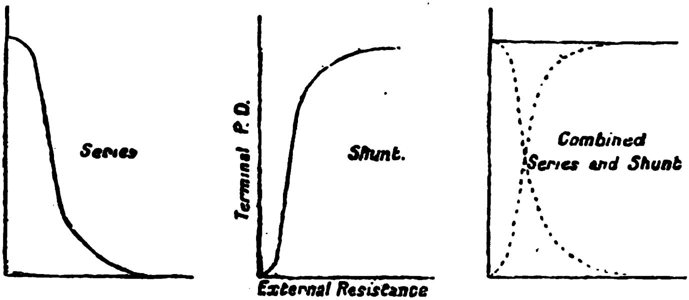


Fig. 240. Voltage Curves of Series, Shunt and Compound Dynamos.

Question 24. What relation has field strength to speed of motor?

Answer. The weaker the field the faster the speed, for the motor must revolve fast to generate its proper counter E. M. F.

Question 25. What relation has armature strength to speed of motor?

Answer. The greater the armature current the greater the speed.

Question 26. What effect on the power of motor does field and armature strength have?

Answer. The greater the field and armature current the greater the power.

Question 27. What is a ring winding?

Answer. One which passes over and under around the core, a space being left between shaft and core to accommodate winding.

Question 28. What is a drum winding?

Answer. One where all winding is on the outer surface of core.

Question 29. Upon what does sparkless commutation of current depend?

Answer. (1) The more commutator bars the better, there being less voltage and therefore tendency to spark between bars. The average railway motor has from 100 to 125 bars on commutator.

(2) The fewer the ampere turns on the armature in comparison to the ampere turns on the field the less sparking.

(3) The more turns short circuited by the brush when touching two or more bars at once the greater the tendency to spark.

Question 30. What is a shunt field?

Answer. One whose coils are placed as a shunt across the brushes. It carries a small current.

Question 31. What is a series field?

Answer. One which carries the main or nearly all the main current and is placed in series with the armature. A small strip of resistance metal is used sometimes to divert a portion of the main current from the series field.

LESSON 30.

POWER HOUSES—SUB-STATIONS.

Power Houses.

The power houses or generating stations of our electric traction systems are nearly all A. C. installations. This is because the transmission to the trains is done by all alternating or partly alternating and partly direct current. Thus it happens that though trains may be operated A. C., D. C., or both, the power house is generally an A. C. plant.

Perhaps the greatest difference between the plants serving the electric divisions of our steam roads, and those of the large city systems is size. The city system plant is apt to be the larger. This occurs because railroads prefer to have several plants strung along the line so that no point of line shall be too far from a station. The city systems operating a network of tracks all fairly near the station, usually rely on one or two big plants.

Another reason is that steam roads coming into electrical operation at recent dates have taken advantage of the steam turbine, which will make a smaller plant for same capacity.

Figure 241 shows the comparatize size of the 5000-K. W. engine-alternator and 5000-K. W. turbine-alternator, both of which are installed in the Interborough Railroad plant in New York.

The large marine engine type, using the revolving element of the dynamo as part or all of its flywheel, seems the favorite engine unit.

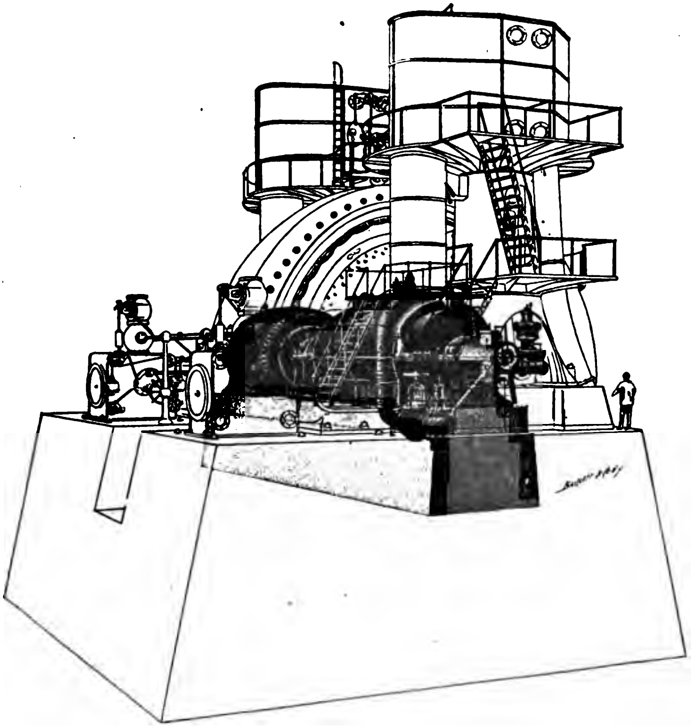


Fig. 241. Comparison of Space Occupied by same Kilowatts of Engine and Turbine Unit.

Figure 242 shows a 2500-K. W., 600-volt D. C. generator in the plant of the Providence, R. I., city system. Its actual size can be judged by height of the hand railing around the pit.

The Interborough plants in New York are both large. Fig. 243 shows the set of 5000 K. W., 11,000 volts, 263 ampere, 25 cycle, 3 phase alternators run by 7500 H. P. marine type engines at 75 revolutions per minute. These

Fig. 242. Engine Generator of 2,500 K. W.

are in the 59th Street plant. The same type of generator is installed in the 74th Street plant. A view in the latter plant (Fig. 244) shows the rear of the same kind of machine as shown in Fig. 243.

The typical turbine-generator plant is shown in Fig. 245. While machines of this illustration are small capacity. (400 K. W.) the lowness of the ceiling is well shown.

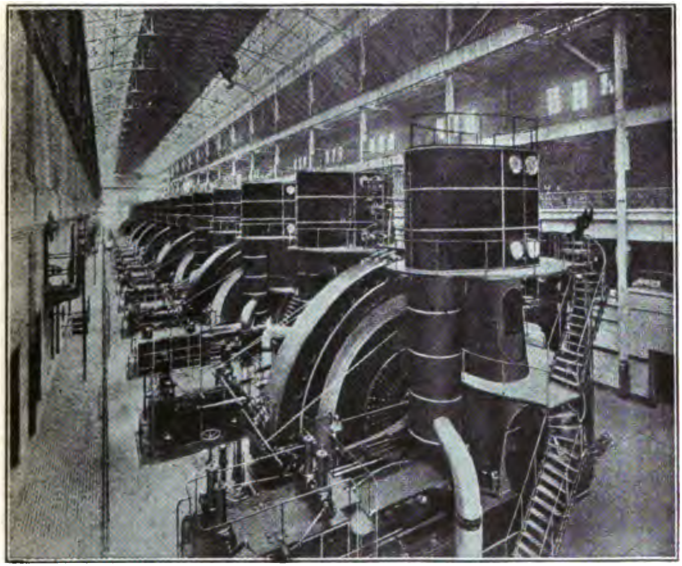


Fig. 243. Set of 5,000 K. W. Engine Alternators, Interborough Plant, New York.

Figure 246 shows a turbine unit of larger size.

Figure 247 shows another turbine plant and Fig. 248 is a view of a turbine unit installed along side of an engine unit.

Turbine Generators.

A 1500 K. W. turbine unit is shown in Fig. 249, and one with a 7500 H. P. turbine and 5000 K. W. alternator is shown in Fig. 250.

Fig. 244. Rear view of same kind of Machines as Fig. 243. Interborough Plant, New York.

The stationary armatures of such units are similar to the engine type, but are small in diameter and longer. Fig. 251 shows armature of a 1000 K. W., 2400 volt, 2 phase unit, while Fig. 252 shows an armature of a sim-

ilar machine wound for 5000 volts. Viewed from the interior the armature cores of Fig. 251 look like Fig. 253.

Owing to the high rate of speed at which a turbine revolves the revolving field is made bi-polar. The one in Fig. 254 has the lower coils in place, but the upper

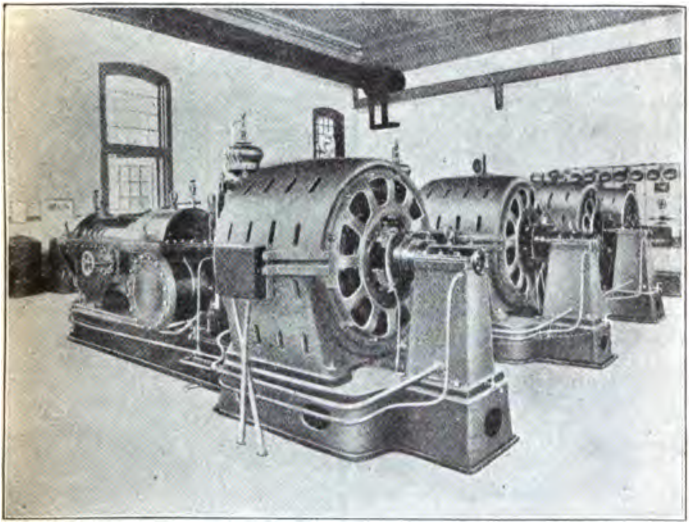


Fig. 245. Plant of 400 K. W. Turbine Alternators.

half is not yet wound. These two coils make the field core a large magnet with opposite polarities at top and bottom.

The core of a 6000 K. W. revolving field is shown in Fig. 255 to give an idea of its size.

Beside the large units just described the small turbine generators are very much used.

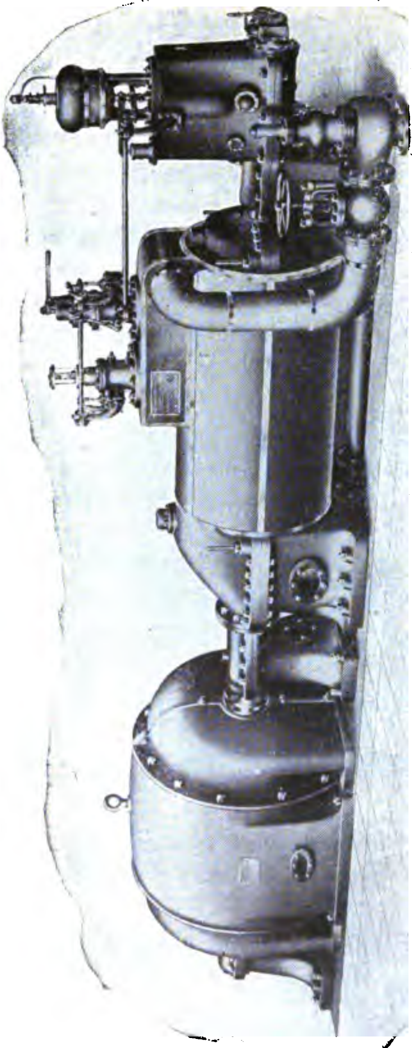


Fig. 246. Turbine-Generator.

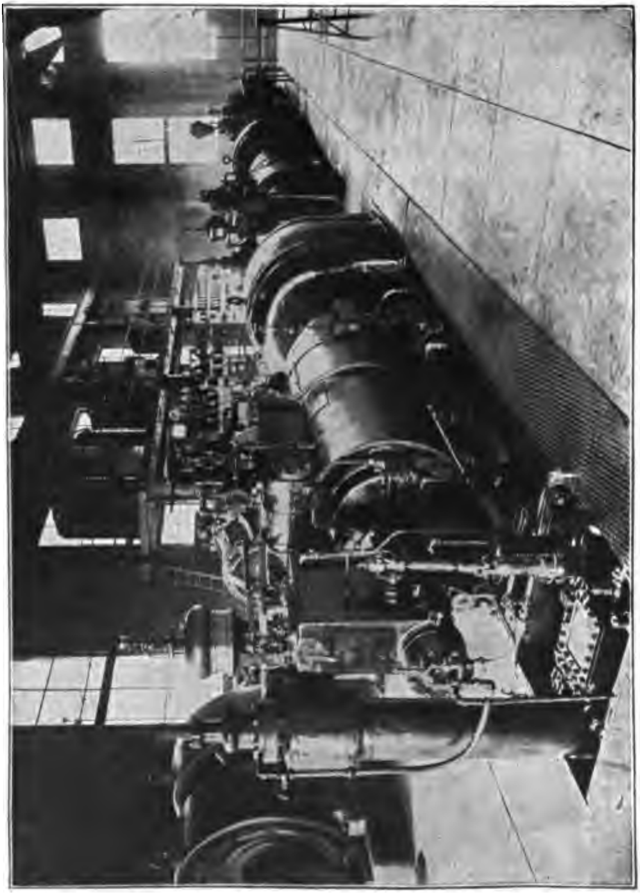


Fig. 247. A Typical Railway Turbine-Generator Plant.

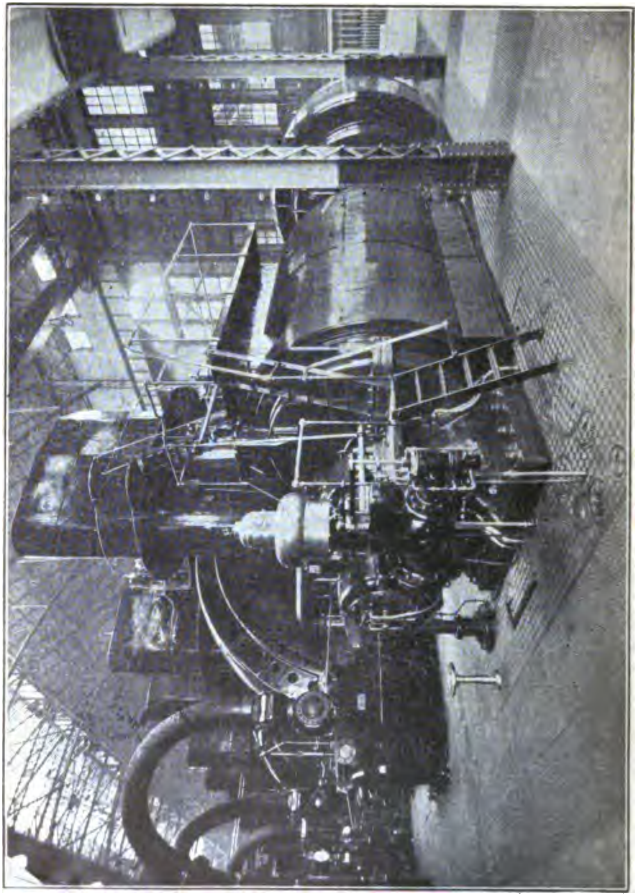


Fig. 248. 5,000 K. W. Turbine-Generator in Interborough Plant among 5,000 K. W. Engine-Generators.

The little 15 K. W. units of Fig. 256 are installed in baggage cars for train lighting, and when protected by a weather proof casing, as in Fig. 257, are installed on locomotives as shown in Fig. 258.

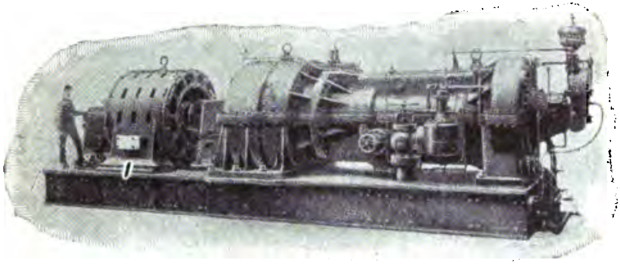


Fig. 249. 1,500 K. W. Turbine-Alternator.

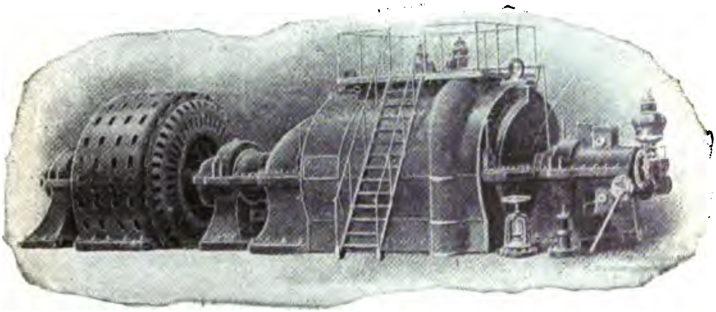


Fig. 250. 7,500 H. P. Turbine and 5,000 K. W. Alternator.

The motion of a turbine is given to the rotating parts by jets of steam blowing against vanes, in much the same way as a water turbine using a very high head of water.

Their value lies in the high rate of speed, no reciprocating parts, ability to work with as high a vacuum as the condenser pumps can furnish, and the small space occupied in comparison with engine units.

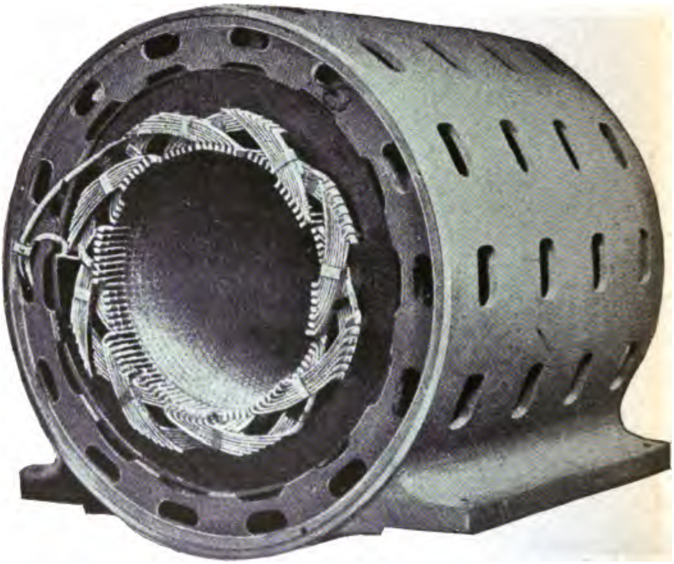


Fig. 251. Stationary Armature of 2,400 volt Turbine-Alternator.

SUB-STATIONS.

The sub-station, the link between the transmission line and the trolley wire or third rail, is a thing we would like to eliminate.

It is an extra building with costly apparatus, needing skilled attendance.

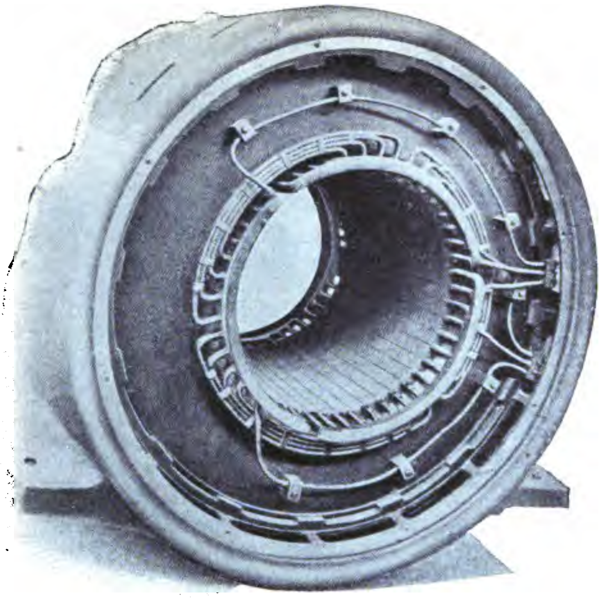


Fig. 252. Stationary Armature of 5,000 volt Turbine-Alternator.

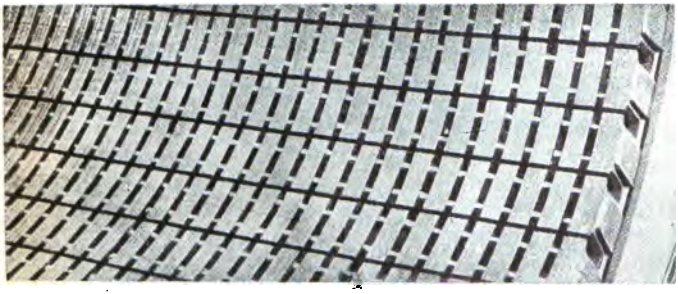


Fig. 253. Interior View of Armature Core of Fig. 251.

With A. C. generation and D. C. utilization of power the sub-station with its rotary converters is a necessity. Where A. C is used straight through the sub-station may be omitted, by having each station fed directly, with a very high tension trolley wire.

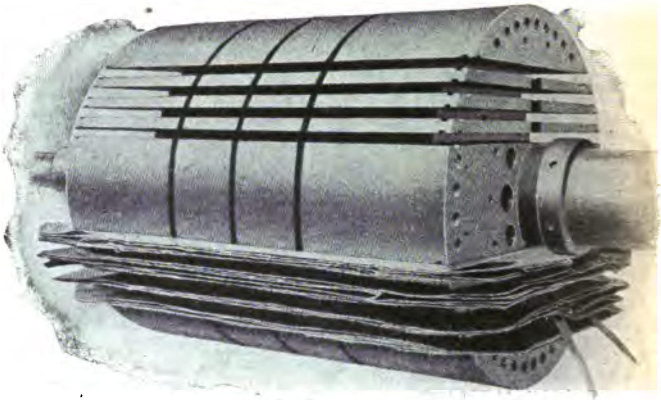


Fig. 254. Rotating Field of Turbine Generator, half wound.

Fig. 255. Rotating Field of 6,000 K. W. Turbine-Generator.

Usually there will be sub-stations containing only transformers. The 22,000 volt lines will feed these transformers and they will feed the line with some lower

voltage. The scheme of placing costly gnerators directly on line, running the danger of static and lightning discharges, seems rather rash.

Fig. 256. 15 K. W. Turbine-Generator for Baggage Car.

Fig. 257. 15 K. W. set with Weatherproof Casing.

When transformers and sub-stations are used the generators may deliver a much higher voltage, for the transformers step it down later, and the absence of any electrical connection between primary and secondary pro-

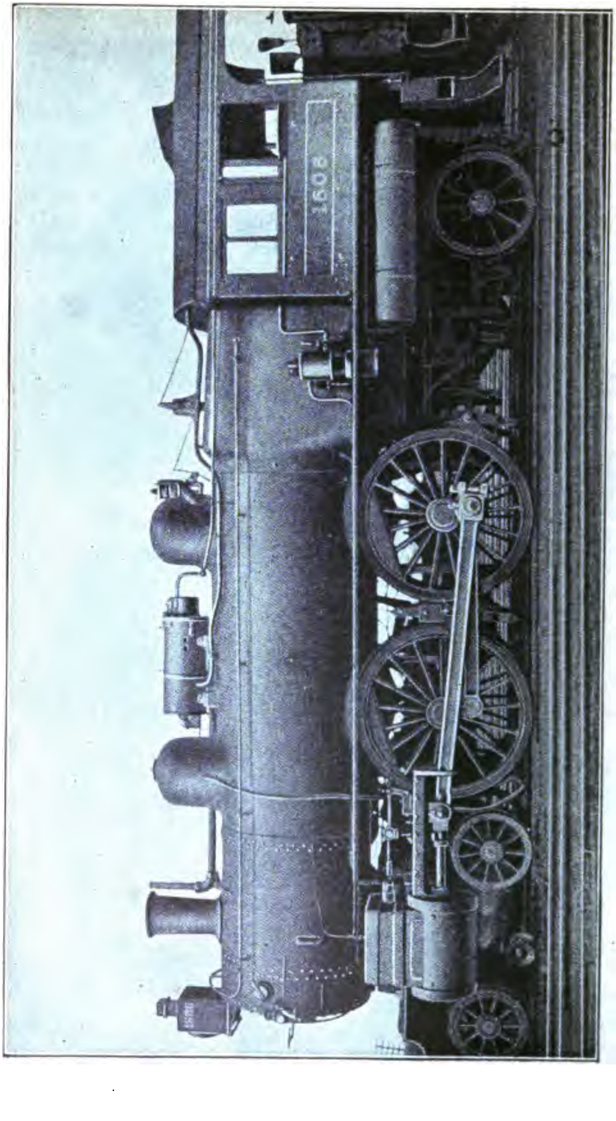


Fig. 258. Turbine-Generator on Locomotive.

tects the generator by absolutely separating it and the trolley wire.

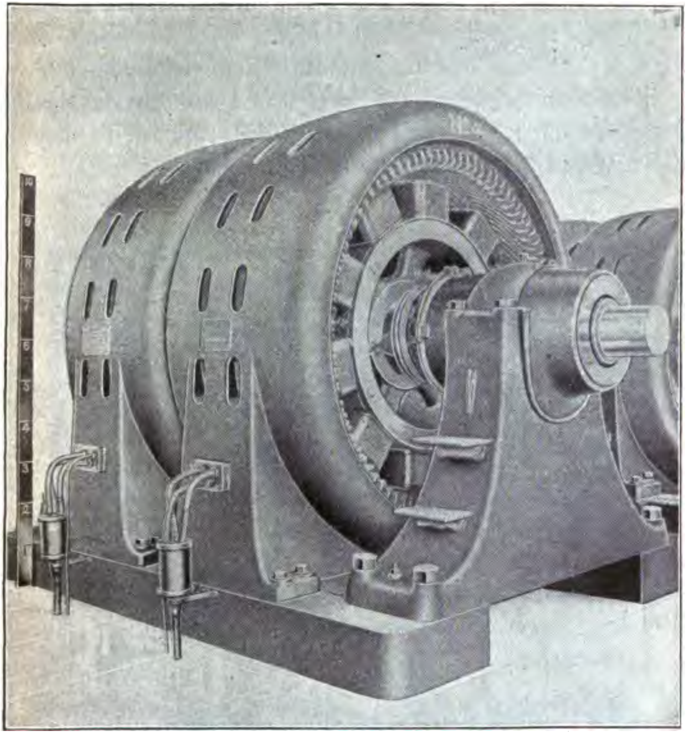


Fig. 259. A Frequency Changer.

One must remember that in A. C. work each car or locomotive carries a small sub-station, *i. e.* a transformer to lower the line voltage to a pressure suitable for the motors.

The A. C. Sub-Station.

One of the great advantages of A. C. traction is the simplicity of its sub-stations. They are small brick buildings containing the transformers for lowering voltage, a simple in-coming and out-going switchboard.

The best frequency for motors is a low one, 25 being now standard. It has been recently proposed to design systems at a frequency of 15.

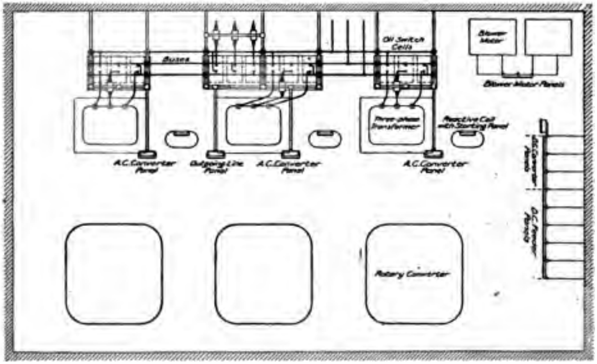


Fig. 260. Floor plan of a Typical Sub-Station.

Both of these frequencies are rather low for lighting and transformers are cheaper to build and operate as the frequency increases.

Railroads by purchase often acquire electric roads which as a side issue furnish light to some municipality. They may continue to do this at the desired frequency from their low frequency plant by installing a frequency charger, Fig. 259.

This consists of two similar machines, one a simple A. C. motor (called a synchronous motor) and the other an A. C. generator built much like an induction motor. It takes in current of one frequency and delivers current at another frequency, higher or lower as desired.

The amount the frequency is changed is determined by the design of the machine and is fixed once for all. There can be no regulation of the frequency, nor in fact is that desired; all that is needed is a change from 25 to say 133 and have it keep at 133.

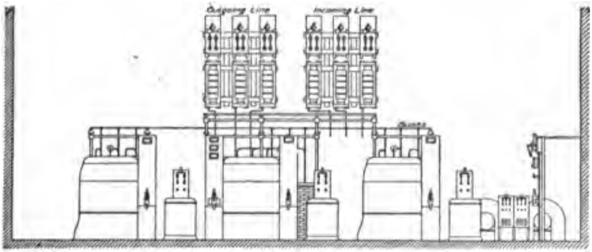


Fig. 261. View of Rear of Station Shown in Fig. 260.

The A. C to D. C Sub-Station.

When D. C. third rail or trolley is used the sub-station contains the step-down transformers which feed the rotary converters, the converters themselves, and the incoming A. C. and out-going D. C. switchboards.

The layout of a typical sub-station is shown in Figs. 260, 261 and 262. The first gives a plan of the station showing position of each piece of apparatus on the floor. The second gives view of the transformers with an A. C. panel for each rotary along side of transformer

on right. On left of middle transformer is the panel for outgoing A. C., which goes to next sub-station.

The starting resistances and switch for the rotaries are between the transformers and between the last transformer and blower panels.

High up on the wall are the two lightning arresters and fuses for the incoming and outgoing A. C. lines.

Figure 262 shows an endwise view of the station which explains itself.

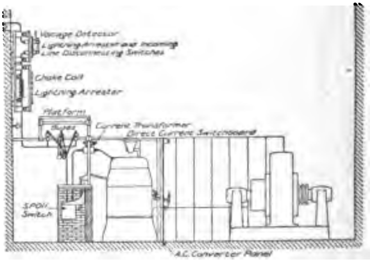


Fig. 262. End View of Fig. 260.

The sub-station shown in Fig. 263 has one complete unit in full view. It consists of a 1000 K. W., 6 phase rotary fed by a set of 3 single phase transformers connected so as to make one 3 phase transformer. These are air blast tvpe.

At the extreme left is an induction regulator operated by a small motor on its top. This motor is controlled from the switchboard. The rotaries in this station are started from the D. C. side, for at least one rotary is always running.

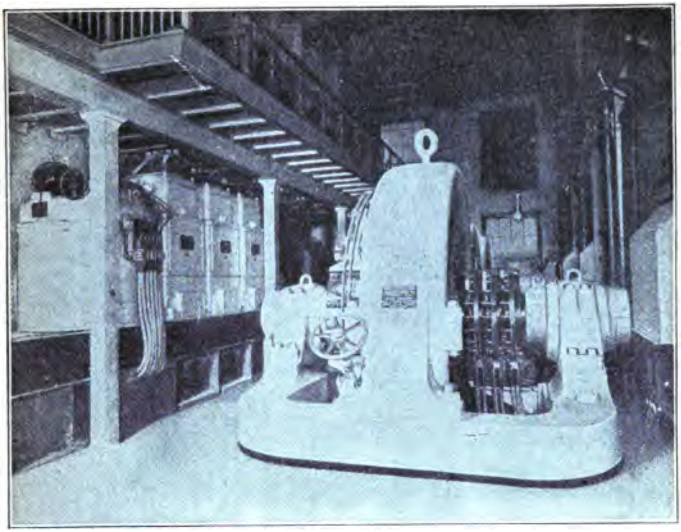


Fig. 263. Sub-Station of 6 Phase Rotaries. Surface Roads, New York.

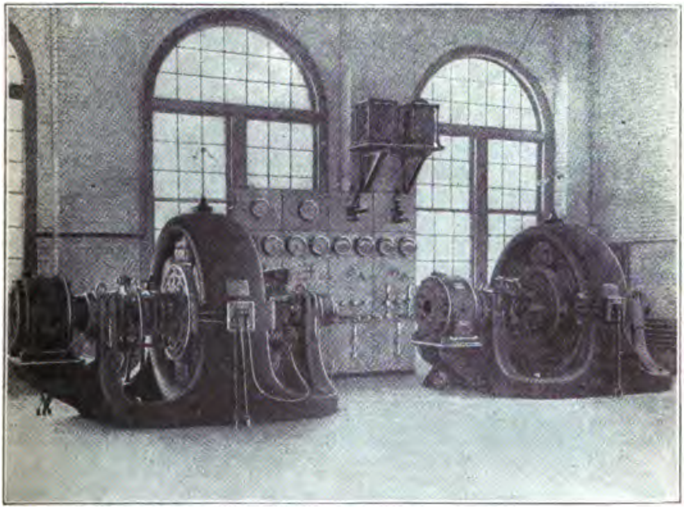


Fig. 264. Sub-Station, Rotaries with Starting Motors, Pittsfield, Mass.

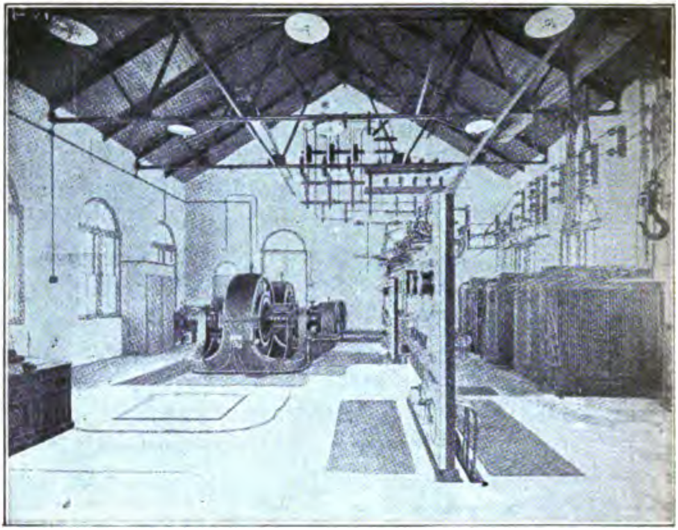


Fig. 265. Sub-Station, Utica, N. Y. Street R. R. Syndicate.

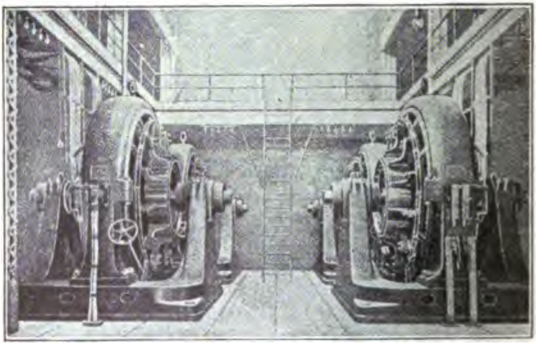


Fig. 266. Interborough Sub-Station No. 8. Four 1,500 K. W. Rotaries.

The station of Fig. 264 is a smaller installation of two 300 K. W., 3 phase rotaries. These are started by auxiliary motors, for the plant is shut down from 2 a. m. to 4 a. m. daily.

Figure 265 shows two 300 K. W. rotaries with a reserve space for another unit. These rotaries have starting motors. The switchboard runs down center of room and behind it are the transformers.

Figure 266 shows four 1500 K. W. rotaries in Sub-station No. 8 of the Interborough Railroad.

Figure 267 shows a rotary converter with switchboard. At extreme rear are the transformers.

Synchronous Motor.

If two similar single phase machines are connected to a line the one may be driven as a generator and the other considered as a motor. This motor will not start when its switches are closed, because the rapid changes of the armature polarity give impulses to move first in one direction and then in another; with the result that motor stands still.

If the motor machine should be revolved by a smaller motor till it is moving at the same speed as generator, or slightly faster, when the switches of the motor are thrown the motor will continue to revolve at generator speed.

Such a motor will carry any load up to 50% overload without the slightest change in speed until suddenly it stops. To get it started again the load must be thrown off and the motor brought up to its proper speed by the auxiliary motor.

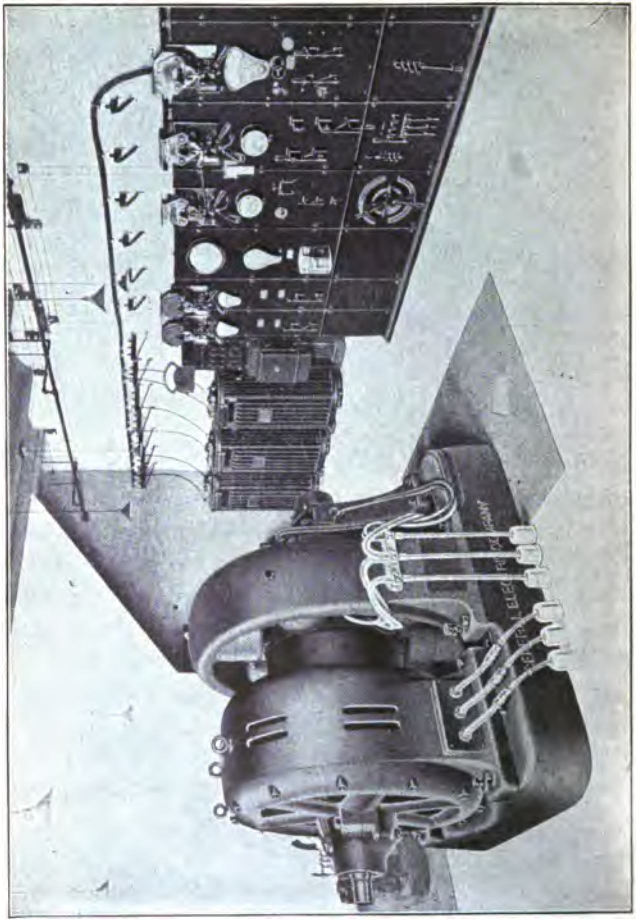


Fig. 267. Sub-Station.

The D. C. for the motor field is supplied to the motor from external source. The strength of the field has no influence on the speed of motor.

The speed is governed by the frequency of generator. If the generator passes 25 pairs of poles a second then the motor will also do so. If the generator and motor have the same number of poles then they revolve the same number of revolutions per minute. A 32 pole generator driving a 16 pole motor goes only half as fast as the motor, for if frequency of generator is 25 the motor must go twice as fast so as to pass the same number of pairs of poles a second.

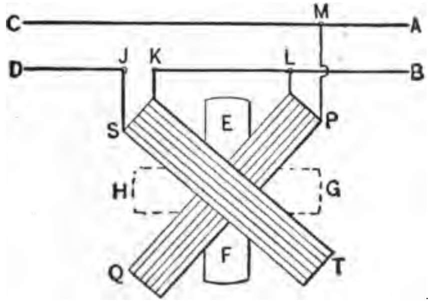


Fig. 268. Induction Regulator.

Induction Regulation.

If the current going to a rotary passed through an auto transformer where part of the coil could be placed in opposition to the rest of it, then we would have an arrangement capable of slightly lowering or raising the voltage applied to rotary, according as the part of coil was in series or in opposition to the rest of the coil.

The *induction regulator* produces the same effect in a little different way. It is as shown in Fig. 268. It con-

sists of a primary P. Q. of a transformer across the line as a shunt and a secondary S. T. in series with one of the mains.

An iron core E. F. when in this position causes the flux to pass through secondary and induce an E. M. F., which is added to the line, while if turned by the handle or by motor into position H. G. the flux through S. T. is reversed and the E. M. F. induced is subtracted from the line. This transformer carries full current, but induces so few volts that the power is small. When only 3 or 4% of its own power is lost, it is a very small fraction of total power delivered to rotaries.

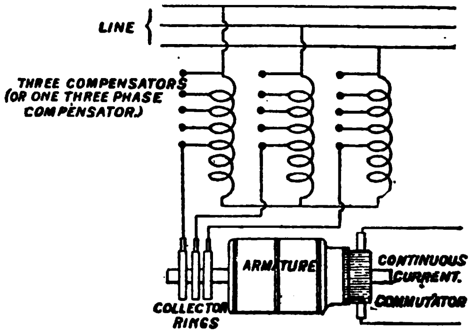


Fig. 269. Starting 3 Phase Rotary with Compensator.

Starting Rotary Converters.

To start from the A. C. mains as a polyphase motor the connections shown in Fig. 269 are used.

The line in this case has a compensator attached and as shown in Fig. 269 the rotary will now receive only a fraction of the line voltage, and starts at slow speed.

As the taps to rotary are moved up the coils the voltage is higher until finally the coils of compensator are cut out entirely and rotary is revolving at full speed, taking full line voltage.

When transformers are between line and rotary the same scheme is applied to the secondaries of the transformer.

To start from D. C. mains a regular starting set is used and operation is like any shunt motor.

Synchronising.

When a rotary is up to speed and ready to be connected to the A. C. line, it must be connected at just the right instant.

This time can be determined by bridging across the connecting switch some lamps in series.

Both the rotary and the incoming line will be operating these lamps. As a result they will flicker. As the right instant is approached the lamps blink slowly until the change from darkness to light takes one or two seconds; then at the time of maximum brightness or darkness close the connecting switch. The lamps may then be disconnected.

Two voltmeters can be combined in one case and made to indicate through a single pointer. When the line and rotary agree the pointer stands in center of dial. These are called synchronism indications or synchronizers.

By synchronism for two alternators we mean that the maximum value of the E. M. F. in each machine occurs at exactly the same instant. They are then in phase, and

in step and in synchronism. In this condition they run as generators in parallel.

If they get out of phase sufficiently they will keep in step and in synchronism but will be in opposition and one will continue to generate while the other will begin to absorb power and act as a motor. This is what is meant by synchronism for an alternator and a rotary converter.

LESSON 31.

SWITCHBOARDS.

A knowledge of switchboards and their wiring is of great value to a power house attendant and of great interest to all the men in operating department.

Switchboards are made up of panels of slate on a frame of angle iron. Each panel is designed for certain work so that a description of the different kinds of panels is sufficient.

The first board to consider is the D. C. outgoing line board, served from D. C. generators.

D. C. Generator Panels.

Fig. 270 shows three generator panels each of which is regularly equipped from a capacity of 250 to 6500 amperes with

1 Carbon break or magnetic blow-out circuit breaker, with telltale.

1 Illuminated dial ammeter with shunt.

1 Hand wheel and chain for operating rheostat.

1 Receptacle for voltmeter plug.

1 S. P.-S. T. field switch.*

1 S. P.-S. T. main switch.

1 Recording Watt-hour meter.

---

*S. T. means single throw.

D. T. means double throw, i. e. the switch has two sets of clips and can be thrown into either of them.

S. P. means single pole.

D. P. means double pole, i. e. opens both sides of circuit.

T. P. means triple pole, i. e. opens every conductor of a 3 phase system.

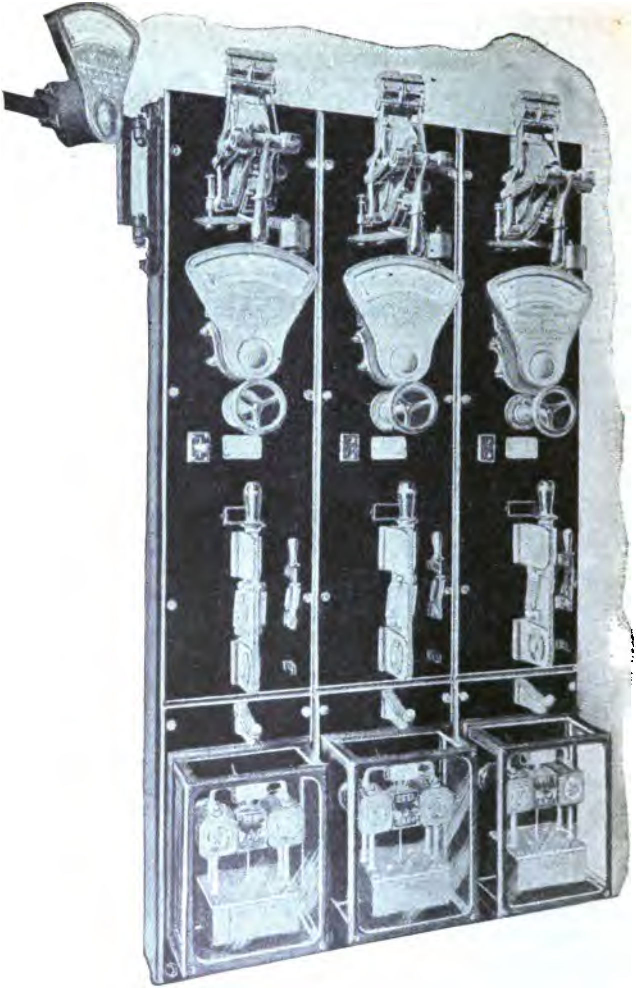


Fig. 270. D. C. Generator Panels.

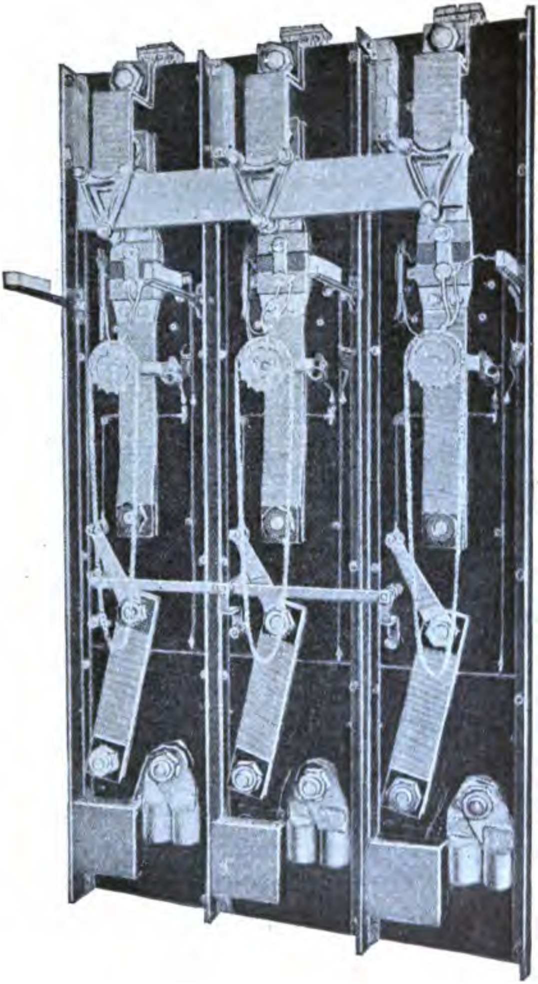


Fig. 271. Rear View of Fig. 270.

A rear view of these panels is shown in Fig. 271.

The best practice puts a main switch at the machine so that the cables from machines to board may be cut off from generator. It is also good practice to run the equalizer cable along in ducts from machine to machine without carrying it to the board.

This equalizer connects the junctions of series field and brush on all machines as shown in Fig. 272; the shunt coils being omitted to simplify diagram.

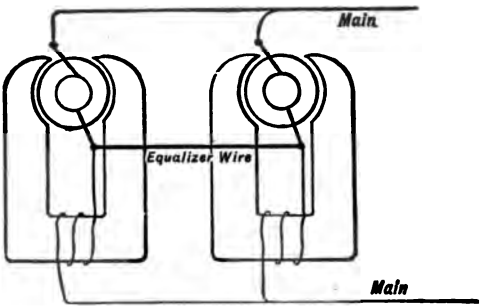


Fig. 272. Equalizer.

It is best to place the main switch and equalizer switch on a pedestal panel as shown in Fig. 273 for moderate capacity and in Fig. 274 for 4000 ampere (and larger) machines. The upper switch being the main switch. The rear view of these large capacity pedestals is shown in Fig. 275.

A better view of the 4000 ampere toggle operated main switch is given in Fig. 276. The quick-break S. P.-S. T. switch is illustrated in Fig. 277.

The field switch, Fig. 278, has a carbon break. Just before the switch opens it makes contact with an extra clip which puts a resistance on as a shunt around the field coils.

Fig. 273. Pedestal Panel for Main and Equalizer Switches. Small Capacity.

Fig. 274. Main and Equalizer Switches for Large Capacity.

If this were not done the fields would act like a kicking or spark coil and their insulation be damaged.

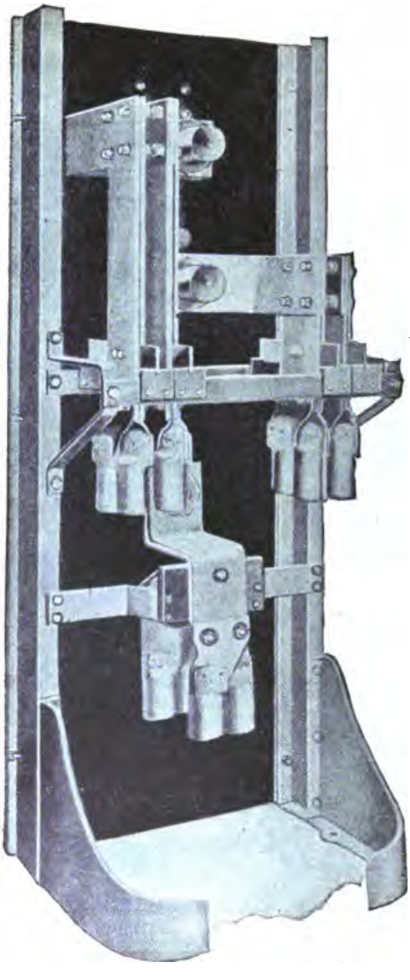


Fig. 275. Rear View of Fig. 274.

In Fig. 279 is seen the diagram of the panel shown in Figs. 270 and 271 when capacity is 800 K. W. or under.

Fig. 280 shows the same panel when capacity is larger. The panel at left is for 1000 and 1200 K. W., the next

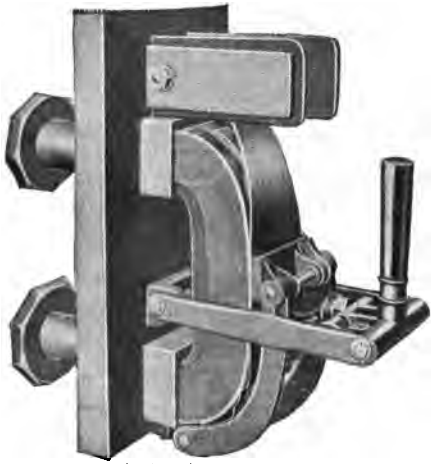


Fig. 276. 4,000 Ampere Toggle Operated Switch. Laminated Main Contact, Carbon Secondary Contact with Magnetic Blowout.

Fig. 277. 3,600 Ampere Quick Break Switch.

for 1500 K. W. and over. The cuts on right side show the back and side view of the 1500 K. W. panel.

The scheme of electrical connections for panel of Fig. 270 is shown in Fig. 281.

D. C. Feeder Panels.

A set of feeder panels for one feeder each is shown in Figs. 282 and 283, a panel for two feeders with separate switches and one ammeter reading sum of both currents is shown in Fig. 284, while Fig. 285 has an instrument and switch for each circuit.

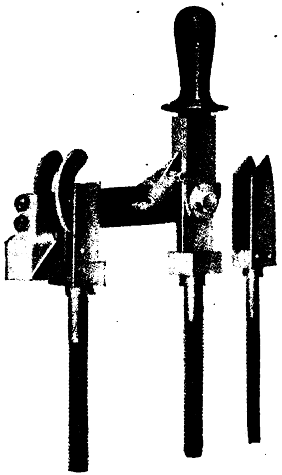


Fig. 278. Field Discharge Switch.

Fig. 286 gives the diagram of these feeder panels and Fig. 287 gives the electrical connections.

With panels as described the way to throw a generator in parallel with other generators already running, the following procedure should be followed:

First—Close main and equalizer switches (on pedestal or panel near machine).

Second—Close field switch (on panel).

Third—Close circuit breaker.

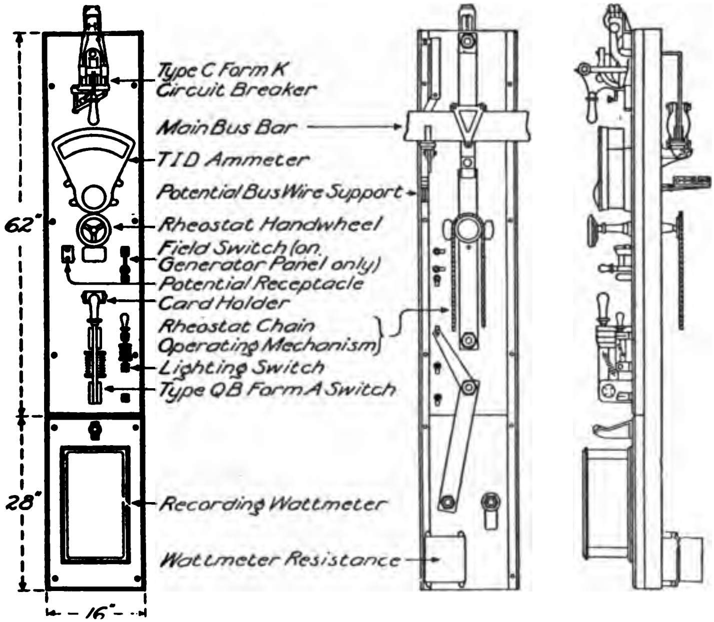


Fig. 279. Construction of Fig. 270 for Small Capacity.

Fourth—Insert potential plug in receptacle and regulate voltage.

Fifth—When the proper voltage is obtained, close the other main switch (on panel).

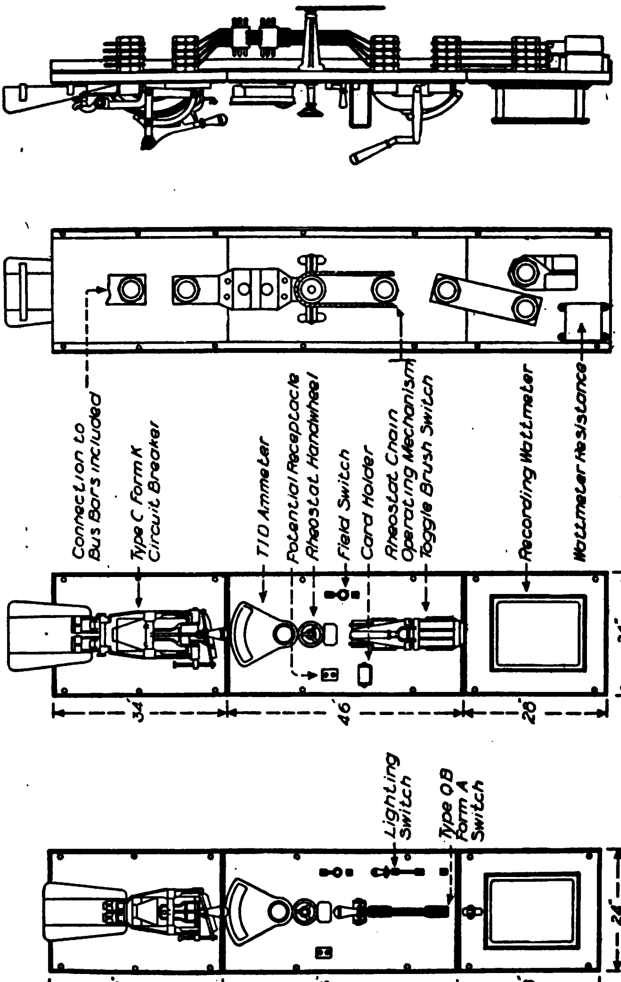


Fig. 280. Construction of Fig. 270 for Large Capacity.

All the above applies to the distributing of the out-put of rotary converters, but as they have some peculiarities they will be considered later.

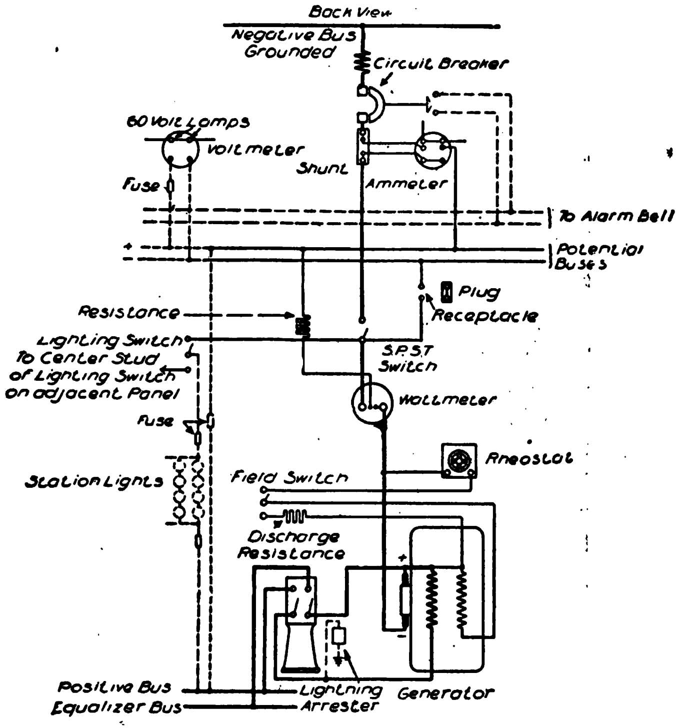


Fig. 281. D. C. Generator Panels

Nearly all railroads are operated by a 3 phase station although the trains are run by single phase A. C. or by converted power as D. C.

The consideration of 3 phase A. C. switchboards will cover all the A. C. power houses.

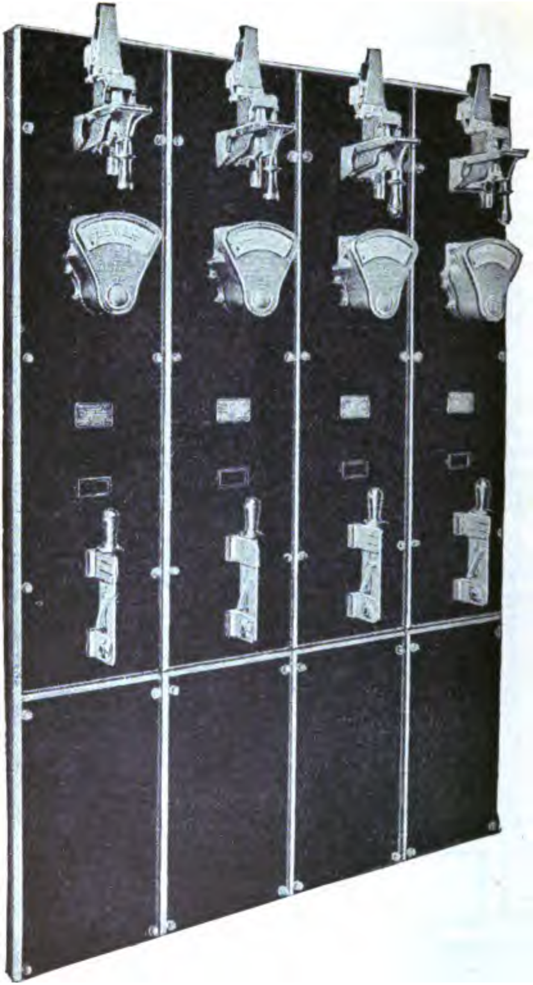


Fig. 282. D. C. Railway Feeder Panels.

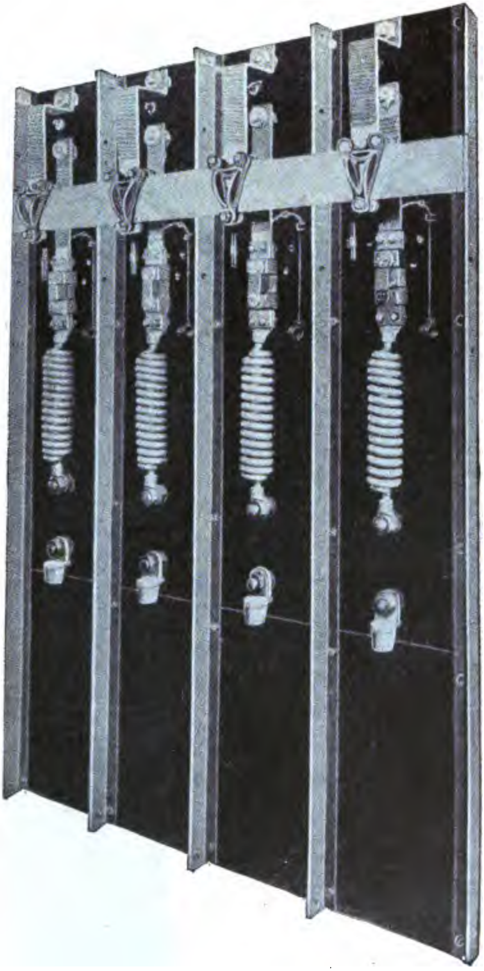


Fig. 283. Rear View of Fig. 282.

Fig. 284. Two Feeder D. C. Panel.

Fig. 285. 1,200 D. C. Ampere Railway Feeder Panel for Two Circuits.

A. C. Generator Panel.

The panel in Fig. 288 contains:

1 Horizontal edgewise balanced three-phase indicating wattmeter, arranged for reading both the kilowatts output and the wattless component.
1 Horizontal edgewise ammeter.
1 Horizontal edgewise voltmeter.
1 Balanced three-phase induction recording wattmeter.
1 D. P. D. T. potential reversing switch for the indicating wattmeter.
1 Four-point receptacle for synchronizing connections.
1 Hand-wheel and chain operating mechanism for field rheostat.
1 S. P. S. T. carbon break field switch with discharge clips.
1 D. P. D. T. engine governor control switch.
1 T. P. S. T. oil switch.
1 Current transformer for instruments.
2 Potential transformers for instruments.

The functions of the instruments are to indicate the current, voltage and kilowatts output of the generator, and the wattless component of the output. For indicating the wattless component and potential coil of the indicating wattmeter is wired to the potential reversing switch, which is normally held by a spring so as to connect the instrument up as a wattmeter. By throwing the switch against the spring into the other position the potential coil is reversed and the instrument reads the wattless component, giving a ready means of detecting

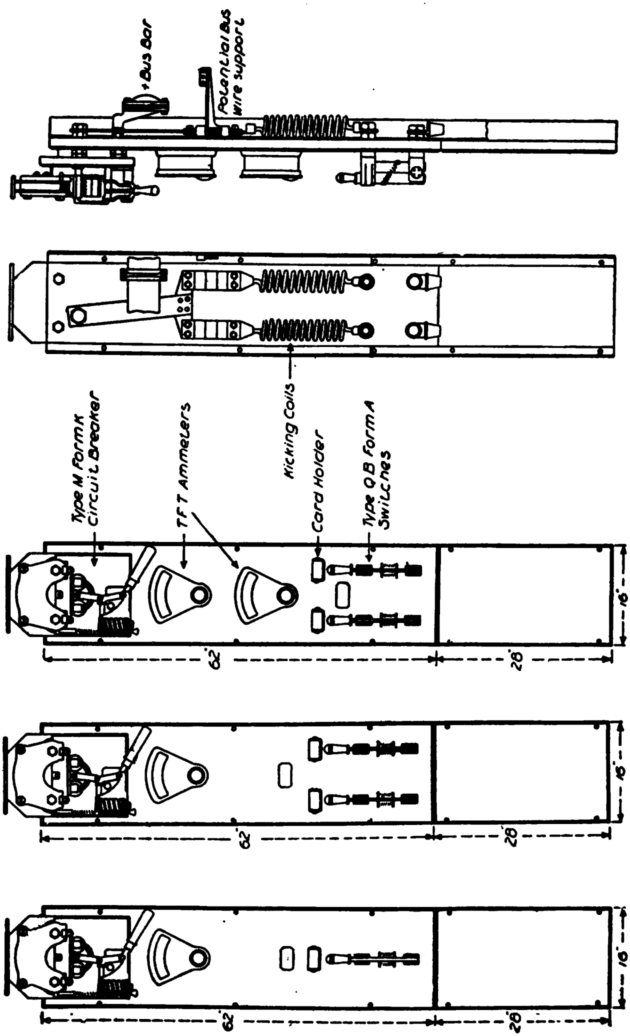


Fig. 286. Construction of Figs. 282 and 285.

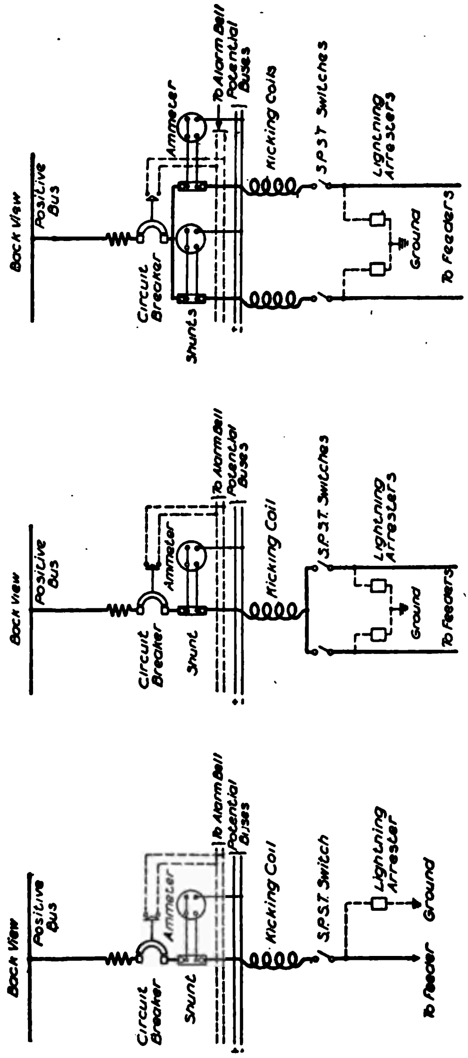


Fig. 287. Three Styles of D. C. Feeder Panels.

Fig. 288.
A. C. Generator Panel.

any currents flowing between the alternators which are operating in parallel.

The engine governor switch is to operate the motor which temporarily controls the governor on engine or turbine when their speeds are being altered to bring two alternators into synchronism or adjusting the division of load when operating in parallel.

The generator oil switch has no automatic overload release, as it is important to keep the generator in service during heavy short circuits caused by trouble on the transmission lines. When such short circuits occur, the generators are immediately relieved by the opening of the automatic line switches.

The diagrams for connecting up generator panels according as transformers are or are not used will be found in Figs. 289 and 290.

A. C. Outgoing Panel.

The panel on left of Fig. 291 contains:

3 Horizontal edgewise ammeters.

1 T. P. S. T. oil switch, with overload release.

3 Current transformers.

Three ammeters—one for each phase—are furnished for each line, to facilitate the detection of unbalancing due to open circuits or leakage. With balanced loads,

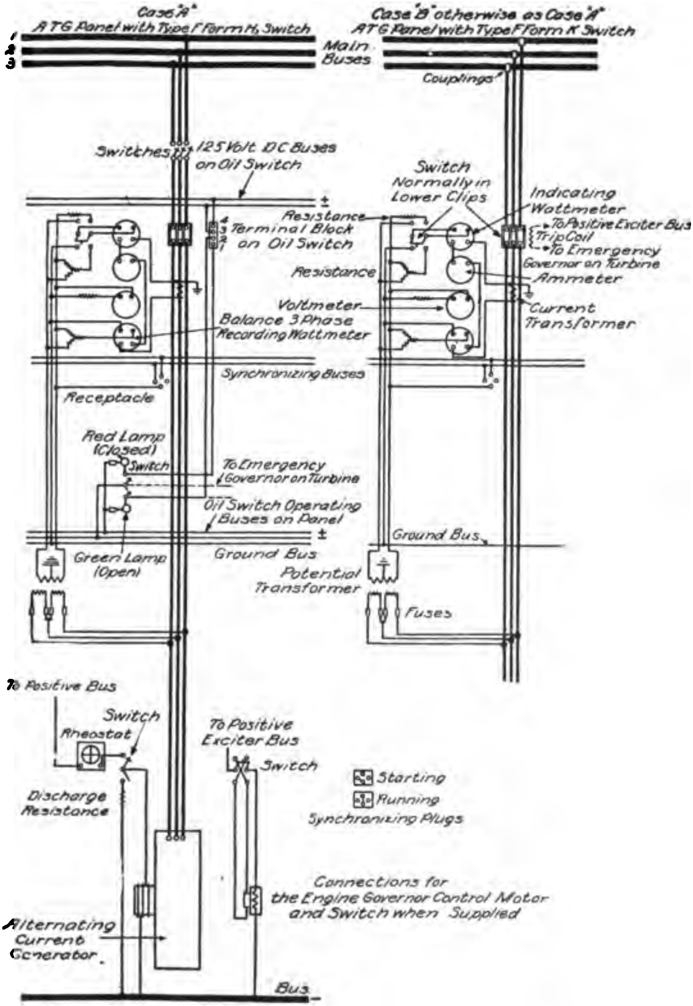
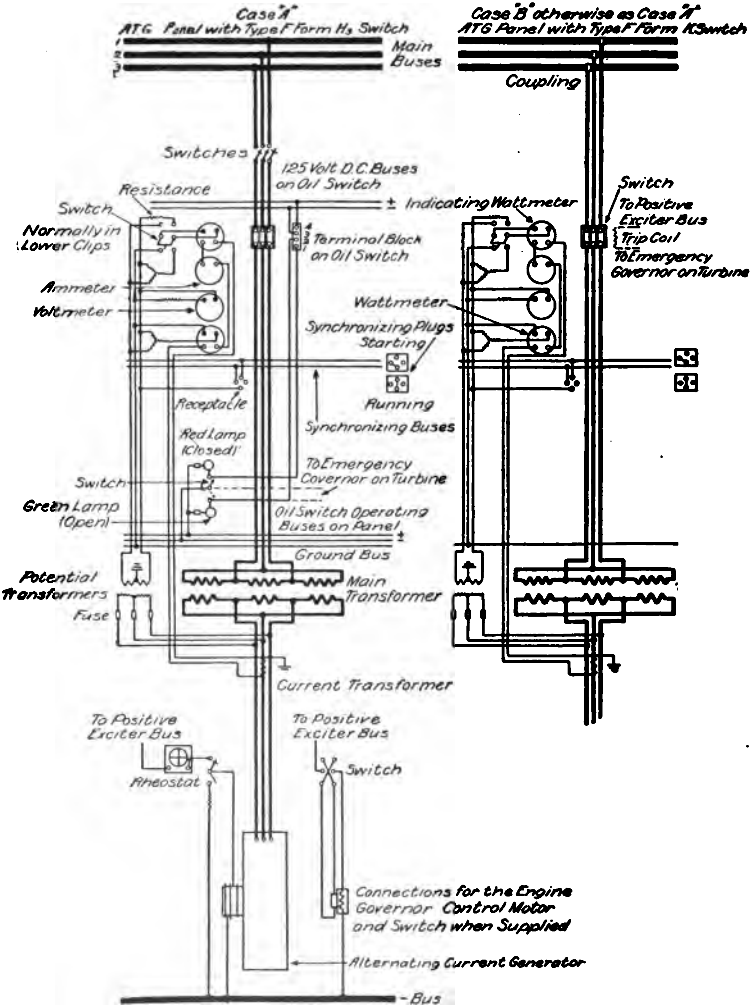


Fig. 289. A. C. Generator Panel without Step-up Transformers.



ALTERNATING CURRENT GENERATOR PANEL FOR GENERATOR WITH STEP-UP TRANSFORMER

Fig. 290. A. C. Generator Panel for Generator with Step-up Transformer.

Fig. 291. A. C. Outgoing Line Panels.

the ammeter pointers should show equal deflections under normal conditions. As the ammeters are arranged in a perpendicular row any variation in the deflections of the pointers is readily detected.

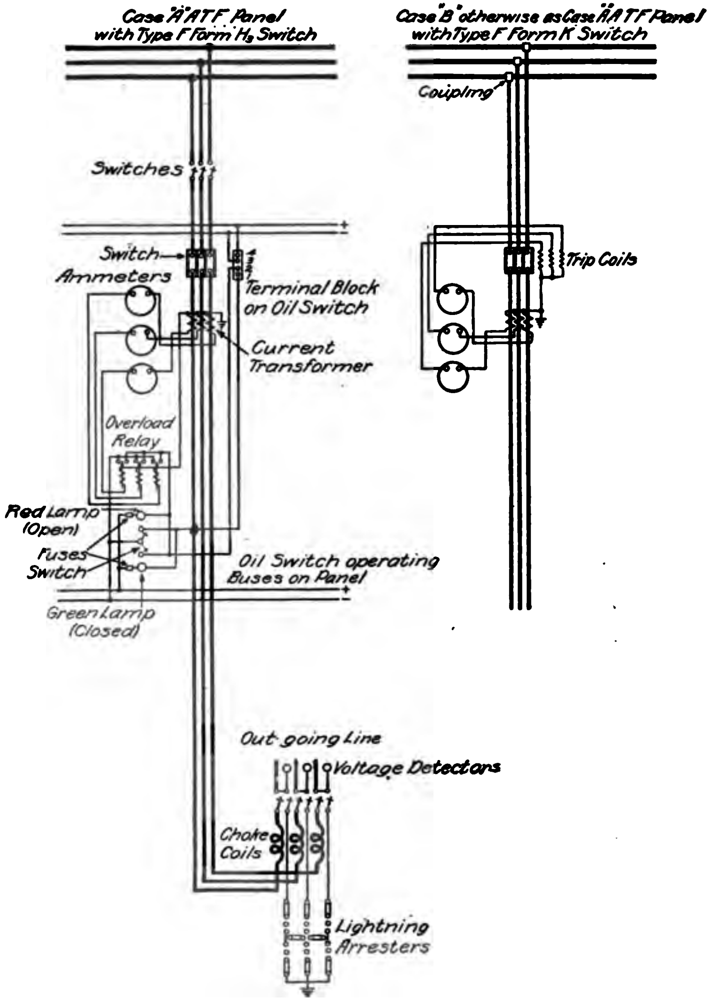


Fig. 292. A. C. Outgoing Line Panel.

The current transformers serve to operate the ammeters and the automatic release on oil switches.

The panel on right of Fig. 291 has but one ammeter and merely has the handle for operating the oil switch. The actual switch being in a brick compartment at rear of panel. The overload relay (3 pole) which trips the oil switch is at base of panel.

Fig. 292 gives the electrical connections of panels in Fig. 291.

Fig. 293. Synchronism Indicator and Exciter Voltmeter on Swinging Bracket.

The swinging bracket of Fig. 293 contains a synchronism indicator, two lamps for synchronizing (practically a duplicate set of synchronizers) and a voltmeter for the station exciter *generator.

To use the synchronism indicator put one plug in on panel of a generator which is running and the other plug in the panel of the generator which is starting.

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*D. C. Generator furnishing current for fields of alternators.

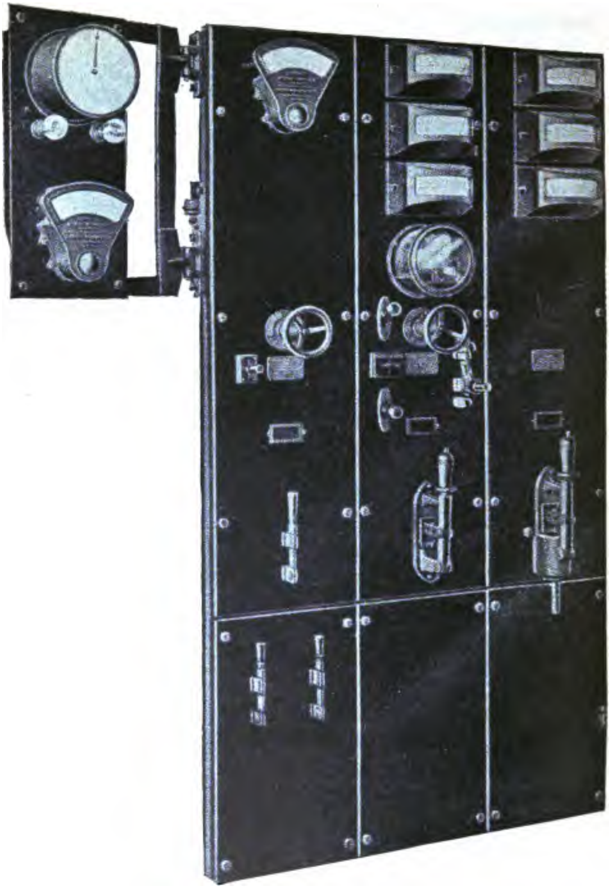


Fig. 294. Main Station Switchboard for One A. C. Generator and One Outgoing Line.

Fig. 294 shows a complete switch board of one generator panel in center, a panel for one outgoing line on the right, an excited panel on left, with the swinging bracket on extreme left.

Fig. 295. Exciter Panel Auxiliary Lighting Switches on Sub-Base.

Such a switch-board would be extended towards the right indefinitely, as more lines were put on the station, by the addition of more outgoing line panels.

Exciter Panel.

Each exciter panel is equipped with:

1 Thomson feeder type ammeter.

1 Hand-wheel for operating rheostat.

1 Two-point potential receptacle connected to voltmeter.

1 S. P. S. T. positive lever switch, with fuse mounted back of panel.

One Exciter Panel in every switch board is furnished with the following additional switches: (as in Fig. 295.)

2 S. P. S. T. lever switches, with fuses back of panel, for the control of station lighting and auxiliary circuits.

On the frame of each exciter there are required the following switches, mounted on a common slate base:

1 S. P. S. T. negative lever switch.

1 S. P. S. T. lever switch for equalizing.

The exciter panels are designed single pole, *i. e.*, only the positive leads of the generators are connected to the switchboard panels and only the positive bus-bar is mounted back of them. The negative and equalizer leads are connected through their switches to the nega-

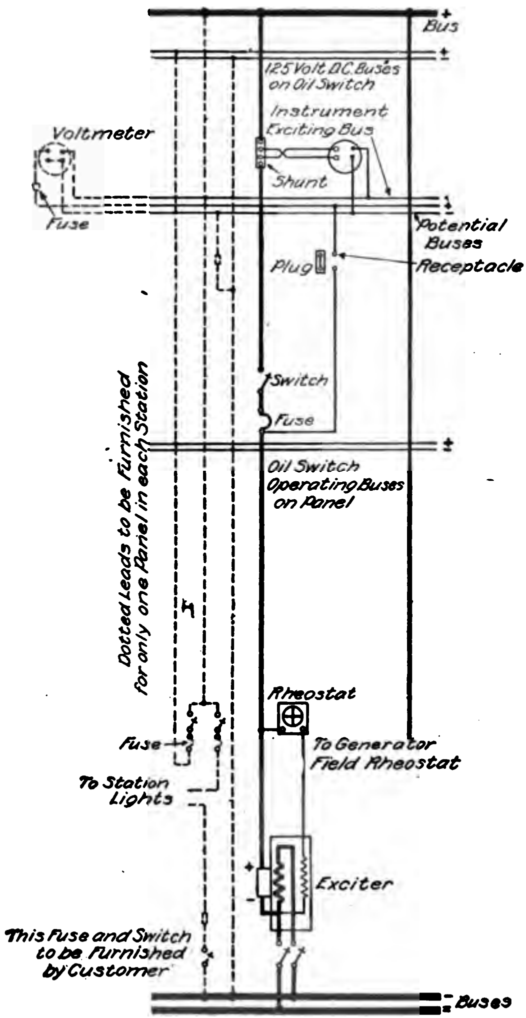


Fig. 296. Exciter Panel.

tive and equalizer bus-bar, which are placed under the floor near the exciters. With the bus-bars of opposite polarity so widely separated there is practically no chance of short circuit of the exciter connections. The positive field leads of the alternators are carried to the panels, while the negative field leads are permanently connected to the negative exciter bus-bar.

Fig. 296 will give the electrical connections of an exciter panel.

Fig. 297. Starting Panel for D. C. Blower Set.

Fig. 298. Main Switch Panel for A. C. Blower Set.

The blower motors running the blowers which cool transformers are of the 3 phase induction type or D. C. shunt motors.

The D. C. motors are started by the regular starting box, Fig. 297.

The current to an induction motor is controlled by a switch like Fig. 298, if from auxiliary low voltage buses or from an oil switch on a panel like Fig. 299, if full station voltage is used.

The actual starting is done by a switch as in Fig. 300, which is between secondaries of transformers or reactance coils and the induction motor.

Fig. 301 shows connections of an induction motor to main buses, using an oil switch and a starting switch.

The operation of several sub-stations on a single line is generally recognized as good practice, especially for interurban systems on which the traffic is not very dense.

To insure continuity of service in the event of line trouble, it is expedient to sectionalize the line at every sub-station that is located at an intermediate point of the line. This sectionalizing is accomplished at each intermediate station by carrying the incoming line to the bus-bars through the air break disconnecting switches which are installed in connection with the arresters, and by carrying the outgoing line through an oil switch. In case of line trouble, this arrangement allows all sections of the line between the generating station and any section on which the trouble occurs to be operated continuously. The power is automatically cut off from the section in trouble by an oil switch in the outgoing line panel equipment of the sub-station at the generating station end of the section, so that the air break disconnecting switches in the sub-station at the other end of the section need never be opened under load.

When duplicate transmission lines are used, two in-

coming line panels and two outgoing line panels are recommended for each intermediate sub-station. The installation of these individual panels facilitates the disconnection of either line of any section and the continuance of the service over the other line of the section without any interruption.

The arrangement of switchboard panels in sub-stations differs from the generating station arrangement, in that the alternating current panels are, preferably, installed individually near their several line or transformer oil switches, thus greatly simplifying the high tension wiring and the oil switch operating mechanisms; while the continuous current panels are grouped into a single switchboard conveniently located. The location of the alternating current panels, transformers, oil switch cells, continuous current switchboard, and machines, as shown in Figs. 260, 261 and 262, is suitable for a 13,200 volt 3 phase sub-station.

Standard sub-station line panels are equipped as follows:

A. C. Incoming Line Panel.

These are only used when lines are in duplicate, and are shown in Fig. 299.

A. C. Outgoing Line Panel.

These are necessary in every sub-station except the terminal one. This panel is shown on left of Fig. 291.

The ammeter on incoming panel must be able to show all the current ever drawn by its own sub-station and those beyond. The capacity of the three ammeters on any outgoing line panel, however, need only be large

Fig. 299. Oil Switch A. C. Panel for Incoming Line Motor Driving Exciter or A. C. Side of Rotary.

Fig. 300. Induction Motor or Rotary Starting Panel.

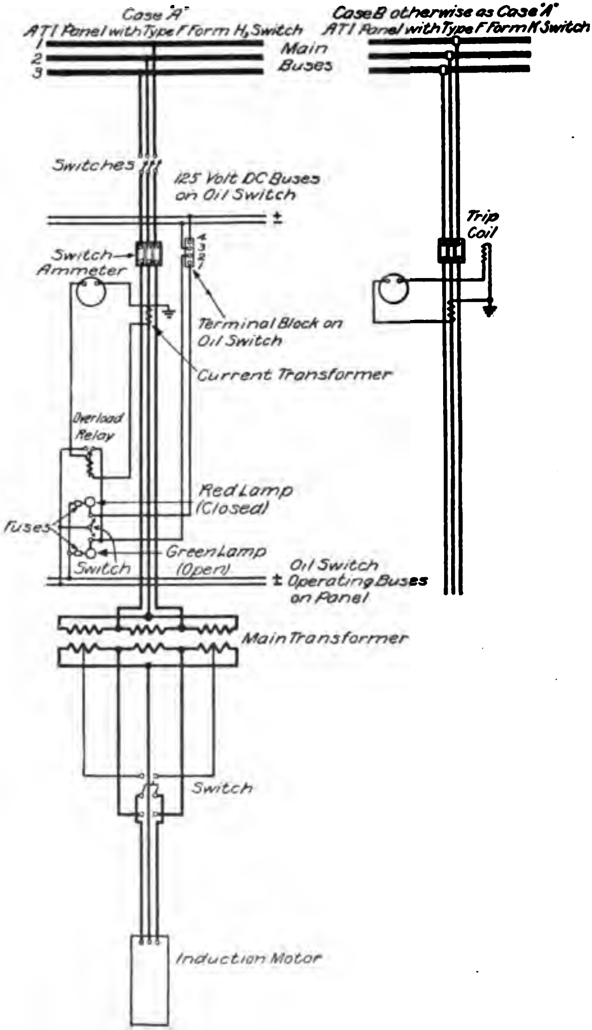


Fig. 301. Induction Motor Panel.

enough to read the maximum load on the line beyond the sub-station in which the panel is installed. As already stated for the outgoing panels of the generating station, three ammeters are furnished in order to indicate, by their unbalanced readings, any open circuit leakage on the outgoing line.

A. C. Rotary Converter Panel.

The panel controlling the intake of the rotary is shown in Fig. 291 (on right). It contains:

1 horizontal edgewise ammeter.
1 T. P. S. T. overload relay for oil switch.
1 current transformer.

Three-Phase Rotary Starting Panels.

In Fig. 300 is shown this panel. The switch is used for starting the converter by connecting two of the three converter leads, first to half-voltage taps and then to the full voltage terminals of the transformer. The third converter lead is permanently connected to the third terminal of the transformer.

Six-Phase Rotary Starting Panels.

As shown in Fig. 302 contains 2 T. P. D. T. lever switches.

These switches are used for starting the converter by connecting three of the six converter leads, first to one-third voltage taps, next to two-thirds voltage taps, and

finally to the full voltage terminals of the transformer. The other three converter leads are permanently connected to the remaining three transformer terminals.

Position of Panels.

The A. C. incoming line panels are connected between the high tension bus-bars and the three-phase primaries of the step-down transformers, and are, therefore, suitable either for three or six-phase converters. Convert-

Fig. 302. Six-Phase Rotary Starting Panel.

ers of capacities up to 400 kilowatts are usually three-phase, and above that capacity, six-phase. The secondaries of the transformers are not carried to the main switchboard but are connected through separately mounted starting panels to the converters. The dimensions of rotary converter starting panels vary with the capacity

Fig. 303. Rotary Output Panel.

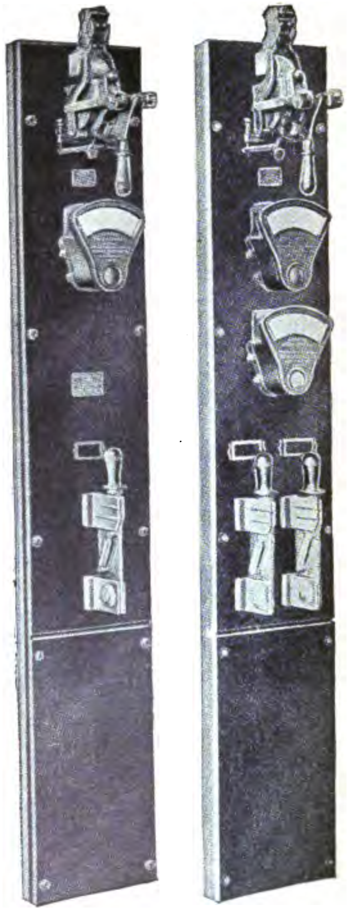


Fig. 304. D. C. Feeder Panels.

of the converters, but they are of suitable size for mounting near the latter. In most cases where compound wound converters with reactive coils are used, the coils are connected between the transformer secondaries and the converters, and the starting panels are mounted on top of the reactive coil casings.

Rotary Output Panels.

These panels are the same as D. C. generator output panels and are shown in Fig. 303.

The circuit breaker is furnished with a low voltage release coil, which trips when the voltage drops to approximately half of its normal value, and with a telltale switch, for connection to an alarm bell which will ring when the breaker opens automatically. To prevent racing of the converter caused by accidental disconnection on the alternating current side, an adjustable speed limiting switch is mounted on the converter shaft. This speed limiting switch operates to short circuit the low voltage release coil when the speed of the converter increases a certain degree above normal, thereby tripping the breaker and disconnecting the converter from the continuous current bus.

The continuous current rotary converter panel is connected in the positive side of the circuit, and the negative side is permanently connected to the grounded negative bus, which is run along below the machine. The equalizing switch, and the switch for opening the shunt to the series field, required for a compound wound rotary converter, are mounted directly on frame of machine.

The advantages of equalizing on negative side and of using single pole switches has been discussed under generators.

D. C. Outgoing Line Panels.

The panels for one and two circuits are shown in Fig. 304.

Fig. 305. Voltmeter Bracket.

Placing Rotaries in Service.

After a rotary converter has been started from the alternating current ends and builds up with the proper polarity, the following procedure should be followed to throw the direct current end in parallel with other machines running:

First—Close equalizer switch (on machine).

Second—Close circuit breaker (on panel).

Third—Insert potential plug in receptacle and regulate voltage.

Fourth—When the proper voltage is obtained close positive switch (on panel).

Swinging Bracket for Voltmeter.

As shown in Fig. 205 a swinging bracket is provided to be mounted at end of board, carrying:

1 Thomson illuminated dial station type D. C. voltmeter.

Fig. 306. Storage Battery Panel.

1 plug for insertion in receptacles on the rotary output panels, thus connecting the voltmeter to the particular machine.

If the rotary when started from the A. C. side comes up with polarity reversed, the voltmeter will swing back of zero.

The polarity of the converter can be corrected by operating the four pole double throw *field break-up reversing switch,* which is mounted on the frame of the converter and included in its equipment. This field reversing switch stands normally in its "up" position, and the operation of throwing it into the "down" position reverses the field magnetization. When the voltmeter needle indicates that the throwing of the switch into the "down" position has established correct polarity, the switch should immediately be thrown back into the "up" position, thereby connecting the field correctly for service.

The operation just described should be performed while the alternating current side of the converter is connected to the low voltage taps of the transformer. When the voltmeter indicates the correct polarity, the converter may be connected to the full voltage terminals of the transformer. The continuous current voltage may then be adjusted by means of the field rheostat, and the machine thrown on the continuous current bus.

When motor operated oil switches are installed in the sub-station, a *storage battery* is used as a source of power for the small 110 volt series motors which operate the switches.

The storage battery consists of:

55 cells, giving 110 volts, the type and capacity of the cells depending upon the number of switches to be operated.

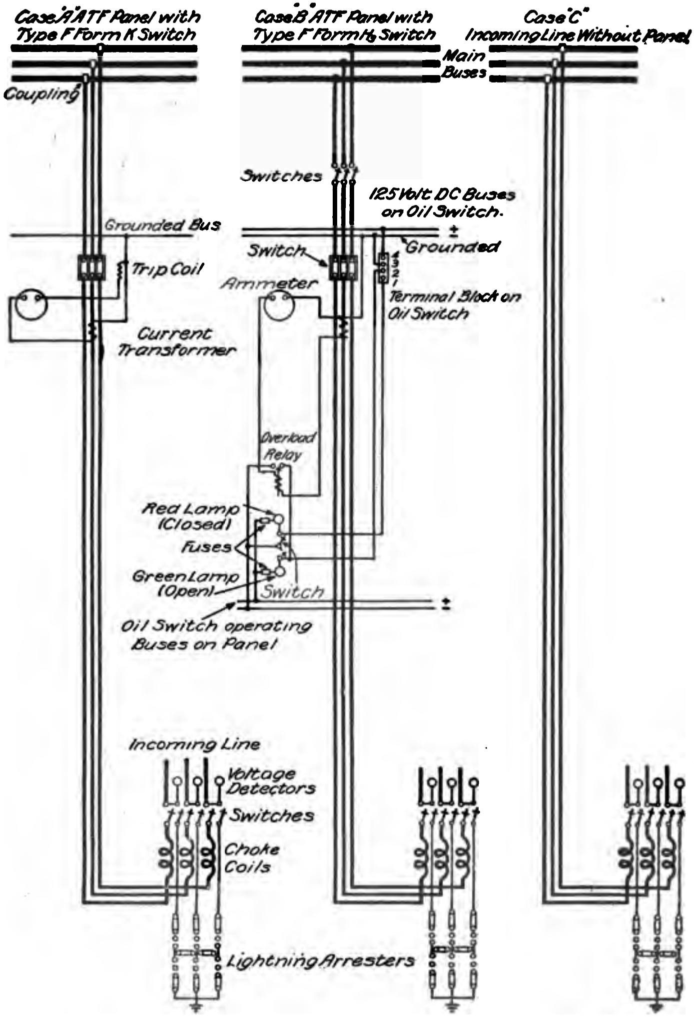


Fig. 307. Outgoing A. C. Line Panel.

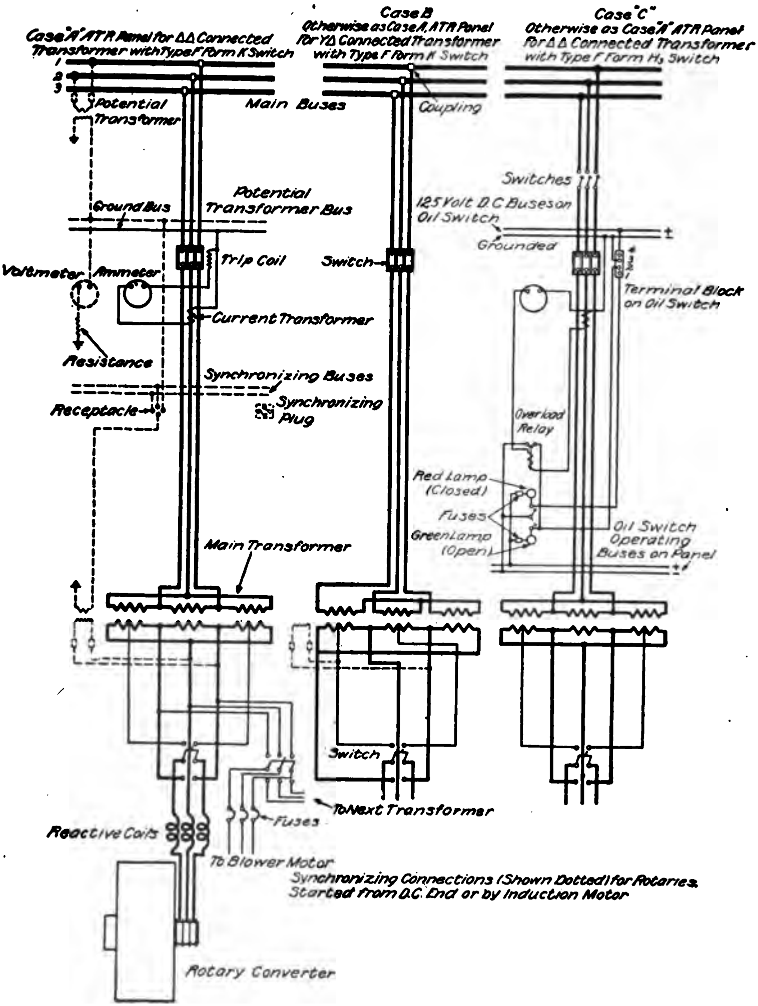


Fig. 308. A. C. End of Three-Phase Rotary.

Storage Battery Panel.

As shown in Fig. 306 contains:

1 Thomson feeder type ammeter, with zero at center of scale.
1 Rheostat.
2 S. P. S. T. quick-break switches.
2 enclosed fuses.

The battery is charged by connecting it in series with the rheostat across the 600 volt bus-bars. The rheostat is provided with a dial switch for regulating the charging current.

Blower Motor Panels

Are required for controlling the induction motor blower sets, which are used with air blast transformers. Each panel, as shown in Fig. 298, contains:

1 T. P. D. T. lever switch.
3 enclosed fuses.

The motors are usually wound for 350 volts, and are operated from the secondary side of the power transformers. The panels are located near the blowers.

As the transformers are not connected in parallel on the low tension side, the double-throw switch is furnished for connecting either of the duplicate blower motors, which are usually furnished, to whichever bank of transformers happens to be in use, as already described for the generating station.

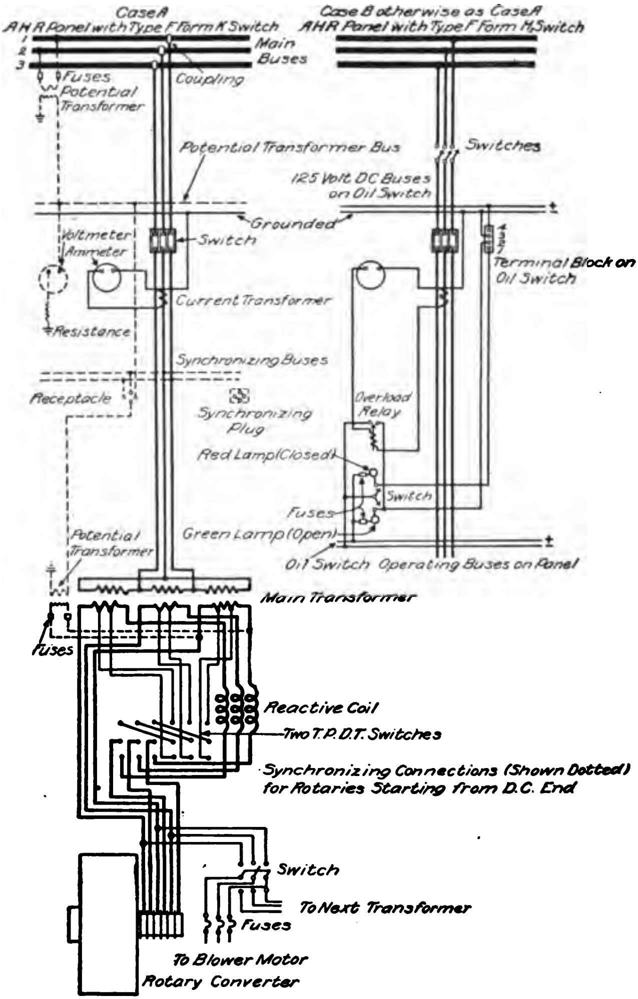


Fig. 309. A. C. End of Six-Phase Rotary.

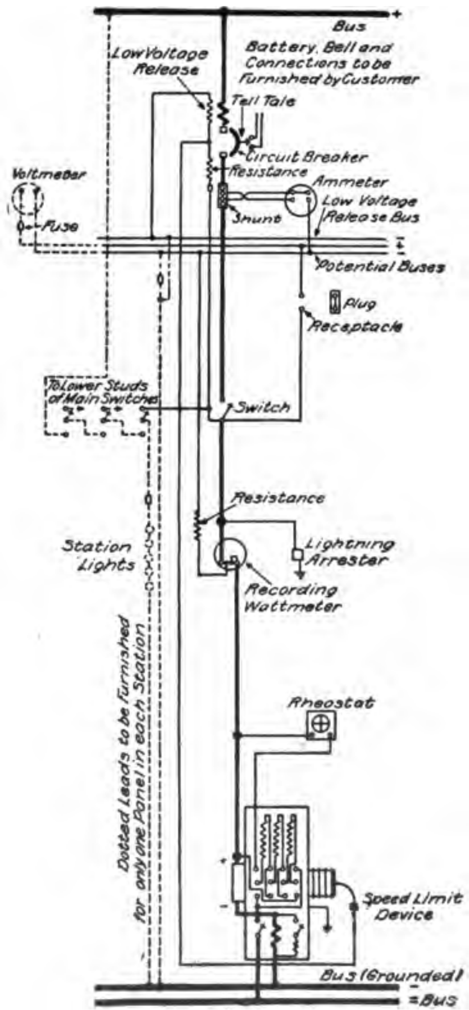


Fig. 310. Rotary Output Panel.

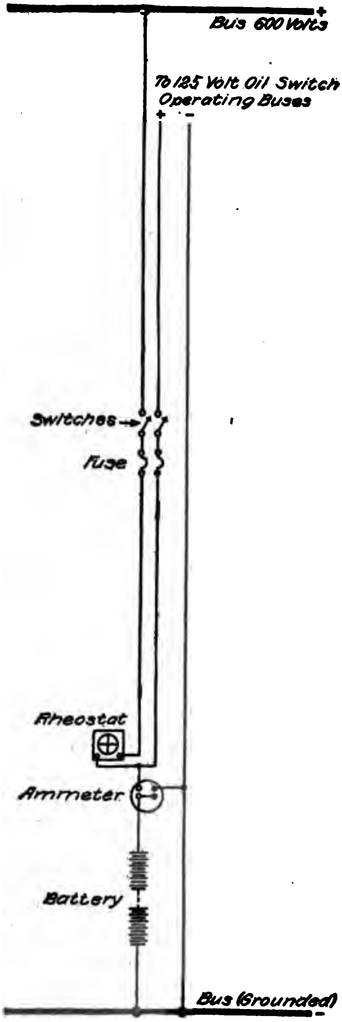


Fig. 311. Storage Battery Panel.

Electrical Connections of Panels.

A. C. incoming lines are shown in Fig. 307.

Connections for a three-phase rotary high voltage panel, low voltage starting panel and blower motor panel are shown in Fig. 308, while similar panels for six-phase rotaries are shown in Fig. 309.

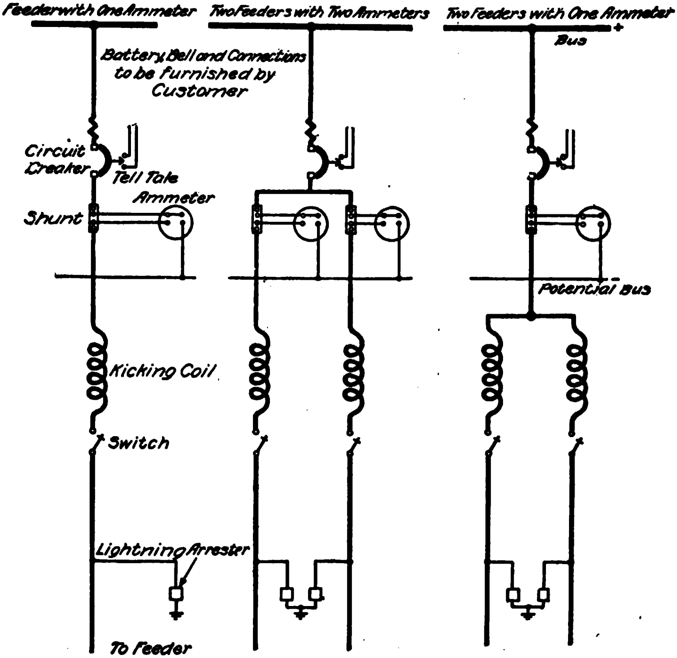


Fig. 312. D. C. Feeders.

The connections of a rotary panel are given in Fig. 310.

The storage battery panel is shown in Fig. 311.

D. C. feeder panels are connected as shown in Fig. 312.

LESSON 32.

Details of Switchboard Equipment and Station Accessories.

Lever Switches of type shown in Fig. 313, are used only to close circuits. When used to open circuits the *Quick Break* type is used, shown in Fig. 277. Half

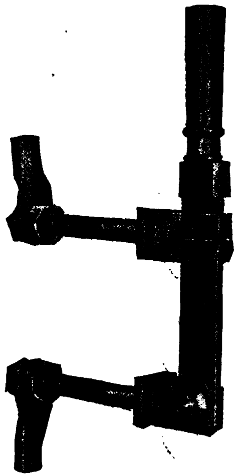


Fig. 313. Knife-blade Lever Switch.

the blade comes out of the clips when the handle is drawn back. This stretches the spring and the tension finally pulls the other half of blade out of clips at great speed, thus preventing much arc.

Field Discharge Switches, Fig. 278, are furnished only on the alternating current generator panels, and as they must be relied upon to shut down the generators under emergency conditions they embody several features of importance. As stated in the description of the generator panel equipment, the field switches are single pole and are furnished with clips for connecting a discharge resistance across the field when the latter is disconnected from its source of excitation, thereby preventing the generation of an excessively high potential, which might puncture the field insulation, when the field circuit is opened. The construction is such that in opening the switch the resistance circuit is closed before the field is disconnected from the exciter, while in closing the switch the resistance circuit is opened before the field is connected to the exciter. By this means all destructive arcing is avoided, for the field can never be broken without shunting it through the discharge resistance, yet the latter is not even momentarily connected across the exciter bus-bars while the switch is being closed.

Oil Switches. The severe conditions which must be anticipated on railway systems demand the use of switching apparatus which will protect the machines and lines from excessive overloads and short circuits without injury to the switches, as the latter must be in condition to put the machines back into service as soon as any temporary trouble has been remedied. These requirements are best met by reliable oil switches, properly installed in brick cells situated apart from the switchboard to prevent any local trouble from spreading.

In case of a dead short circuit on a feeder near the generating station, the current in the circuit which must

be opened reaches a maximum the value of which may be many times the normal capacity of the generators. The automatic feeder switches must be capable of breaking this maximum current instantaneously. The non-automatic switches, on the other hand, are not required to

Fig. 314. Front View of Oil Switch.

open the maximum current, but must be capable of opening the load after the current has dropped to a value which the generator will maintain on short circuit.

Figs. 314 and 315 show the operating handle and the switch mechanism of a three pole oil switch.

A triple pole double throw oil switch for panel use is shown in Fig. 316.

It is often desired to have the switch at some distance from the panel on which it is controlled.

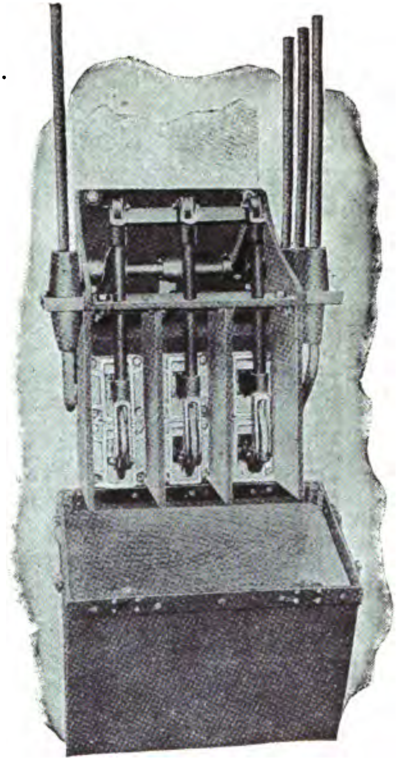


Fig. 315. Rear View of Oil Switch.

In Fig. 317 is shown a triple pole single throw 15,000 volt 300 ampere oil switch. It would be very unsafe to have this on the switchboard.

It is built into a three compartment brick cell at some distance behind board and contròlled by a long rod running from lever on panel. This switch is of the non-automatic type, being used for a main generator switch.

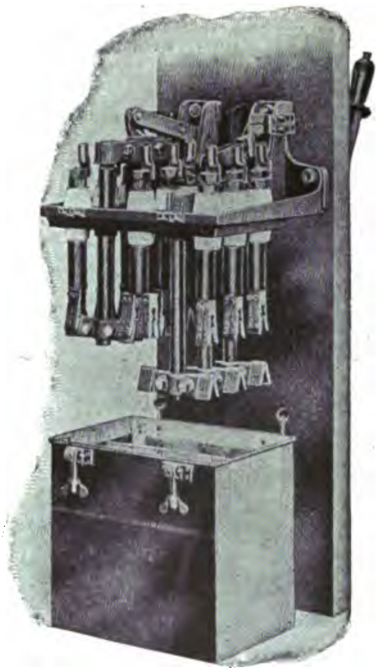


Fig. 316. Three Pole, Double Throw, Oil Switch.

Such switches, when used on transformers, are so far from the panel that some arrangement as in Fig. 318 is used.

Switches at a distance from the board may be controlled electrically if fitted with a tripping magnet and

closed by sending an attendant to the switch. This is very bad practice, as the time wasted and even possibility of closing wrong switch must be considered. The switch in Fig. 319 is operated by two magnets, the left hand one (not clearly shown) opening, the right hand one closing, switch. A small S. P. D. T. switch on panel

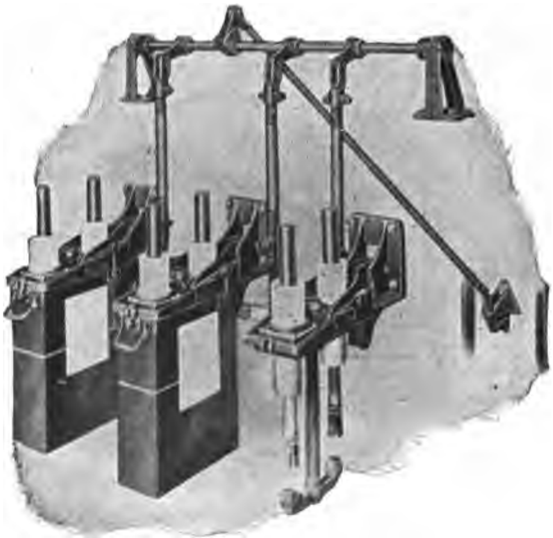


Fig. 317. Oil Switch 15,000 Volt, 300 Ampere Triple Pole, Single Throw. Brick Partitions Not Shown.

controls the two magnets. Large switches, as Fig. 320, are opened and closed by motors. For such a motor switch there will be on the panel:

1 S P. D. T. operating switch for the control of the oil switch motor.

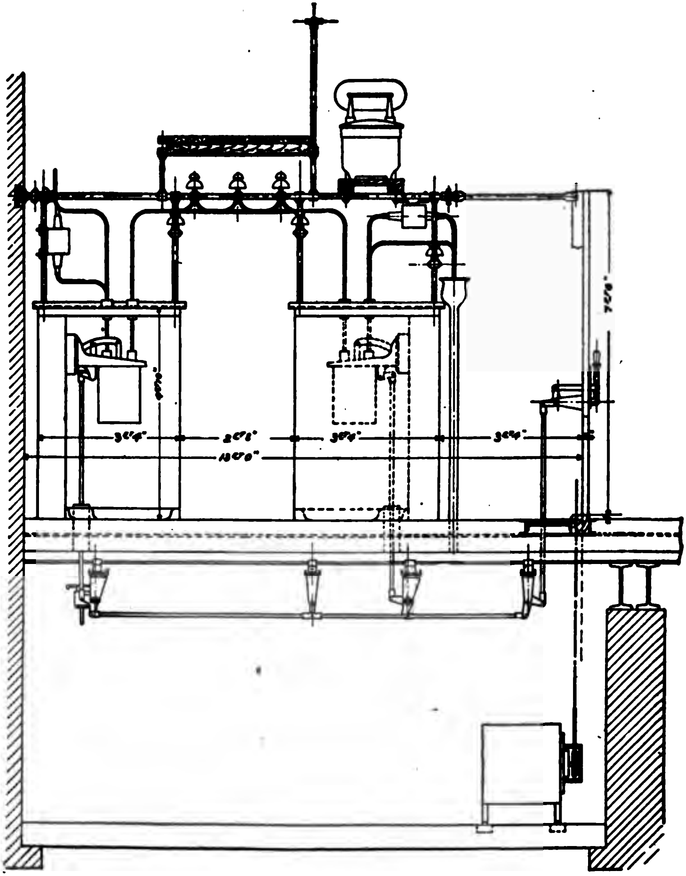


Fig. 318. Arrangement of Remote Control Lever Oil Switches.

2 miniature lamps, one with red and other with green bull's eye.

If the switches must open automatically there is provided in addition to the above:

1 overload relay.

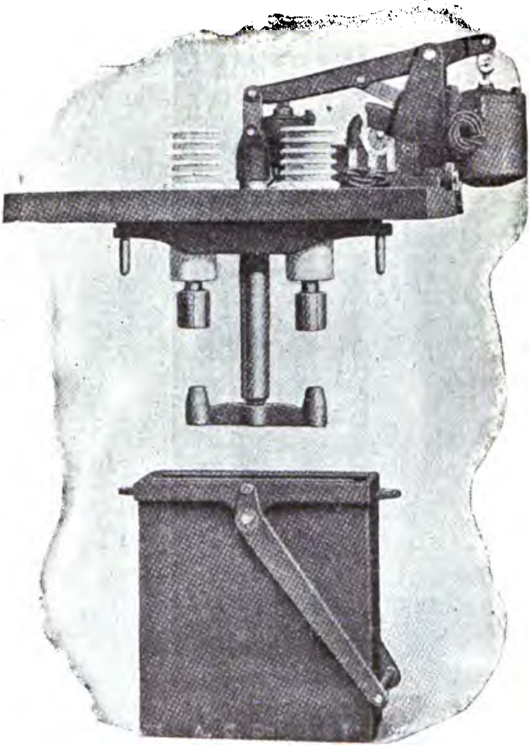


Fig. 319. Magnetically Operated Oil Switch.

The lamps with bull's eyes are controlled by an auxiliary switch attached to the operating mechanism of the oil switch. The opening of the oil switch lights up

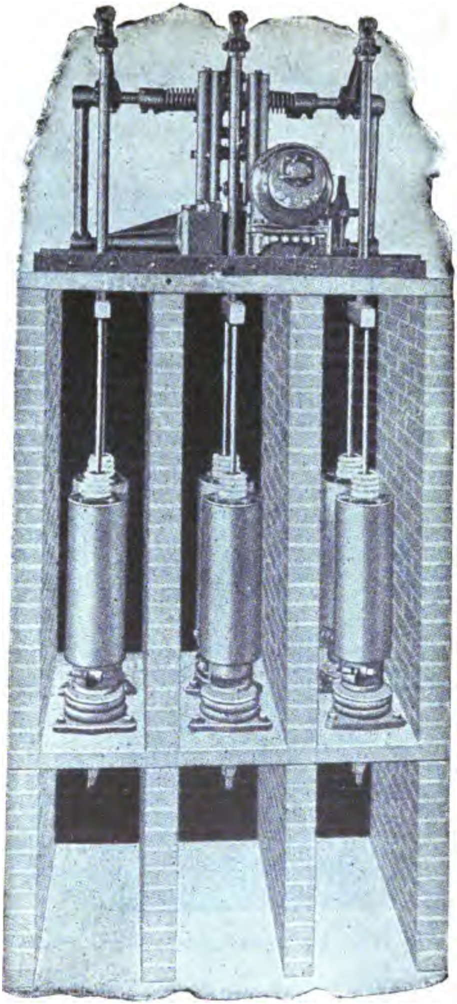


Fig. 320. Motor Driven, T. P. S. T. 13,000 Volts 300 Ampere Oil Switch in Brick Cell.

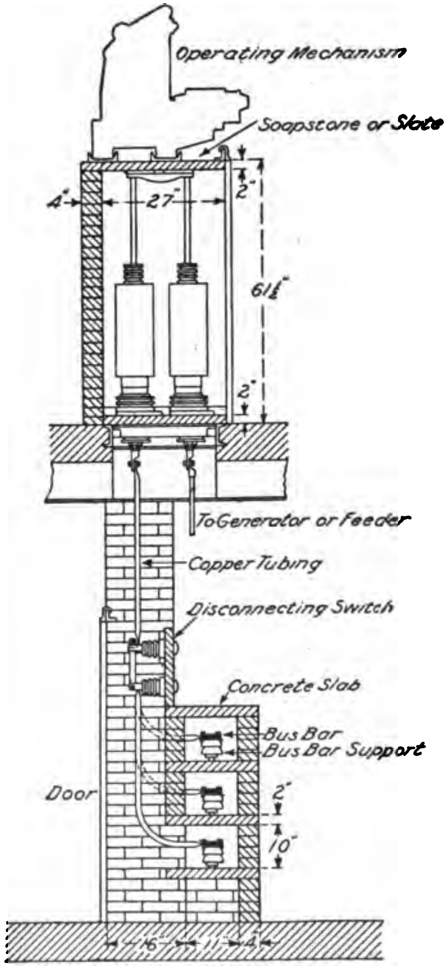


Fig. 321. An Arrangement of 13,000 Volt Buses and Oil Switches, Very Little Floor Space Required.

the green bull's eye, and its closing lights up the red bull's eye, assuring the attendant that the throwing of the controlling switch has been followed by the proper operation of the oil switch.

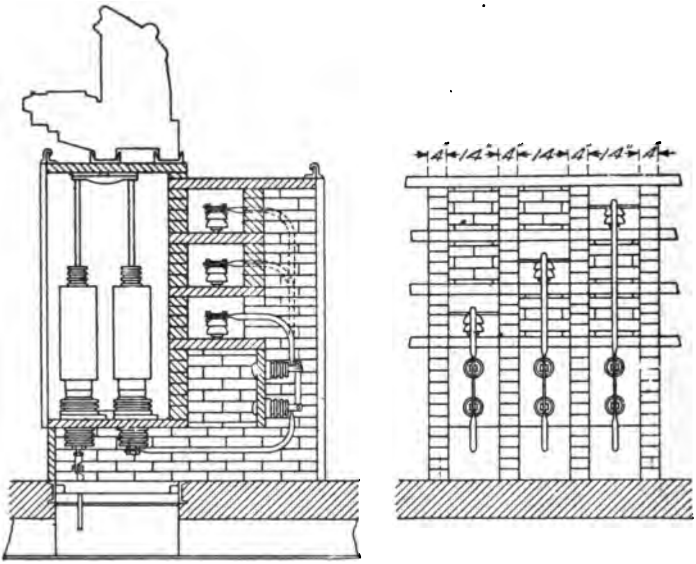


Fig. 322. A More Compact Arrangement Than Fig. 321. Needs More Floor Space.

When the current in the main circuit exceeds a predetermined value the overload relay closes a continuous current circuit, thereby tripping the oil switch.

Under some conditions, however, it is desirable to delay, for a certain length of time, the opening of the switch under its predetermined overload. To accom-

plish this result the overload relay is equipped with a time limit device.

As already stated, all high tension oil switches should be mounted in brick cells situated apart from the panels.

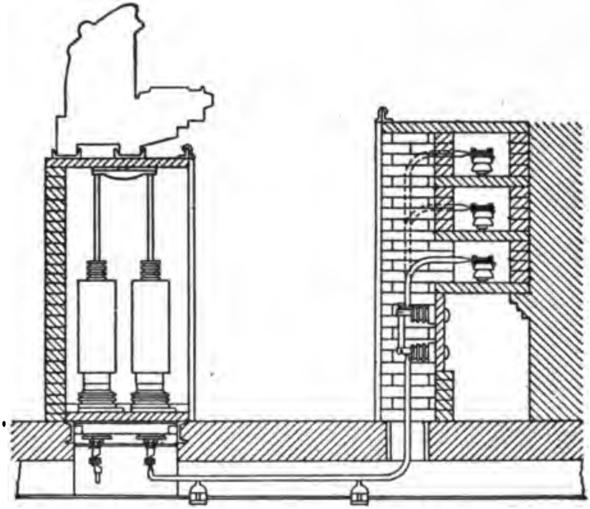


Fig. 323. Arrangement Similar to Fig. 322 When More Space is Available.

The bus-bars, disconnecting switches and oil switches, need not only good insulation but separation. Fig. 321 shows one way of handling a 13,000 volt set. Fig. 322 shows side and rear view of another scheme and Fig. 323 still another way of placing them.

Field Rheostats being of such large size the arrangements shown in Fig. 324 are often necessary. In Fig. 318 the rheostat is on floor below.

Cable Connections. In order to connect large cables to the bus-bars, instrument, and machine terminals, the cables are split and the parts soldered into lugs. Fig.

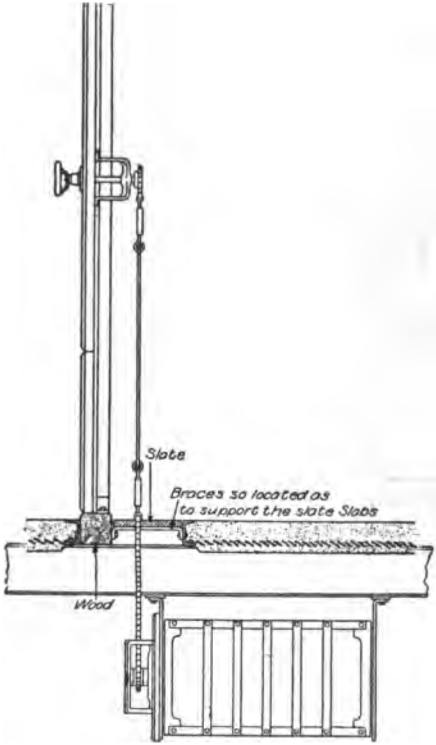


Fig. 324. Mounting and Control of Field Rheostat.

325 shows how *five* of these lugs can be placed on a stud so as to occupy as little end room as possible.

The Voltage Detector, Fig. 326, is a static device having a movable element which is set in rotation when it is

subjected to the line potential. A detector is attached to each conductor of every line, on the line side of the disconnecting switch. A complete set, therefore, consists of three detectors for each line. This device also serves as a ground detector, as its moving element will come to rest when a ground occurs on the conductor to which it is connected.

Fig. 325. Clamping a Five Terminal Cable to Panel Stud.

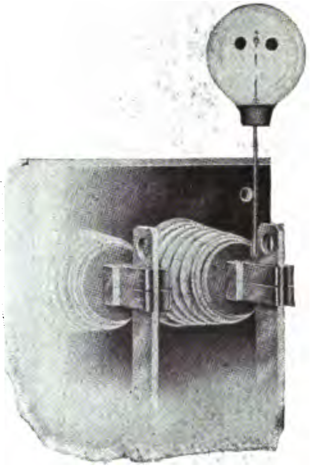


Fig. 326. Voltage Detector, for Circuits up to 15,000 Volts.

Three Single-Pole Double-Blade Disconnecting Switches (Fig. 327) are placed in each incoming and outgoing line, one switch in each conductor. One blade is used for disconnecting the lightning arrester from the line, while the other blade is used for disconnecting the station from the line. Choke coils also are recom-

mended for connection in series with the line between the arrester taps and the switchboard in order to protect the station apparatus. The arresters, switches and choke coils are designed for mounting on the wall at the point

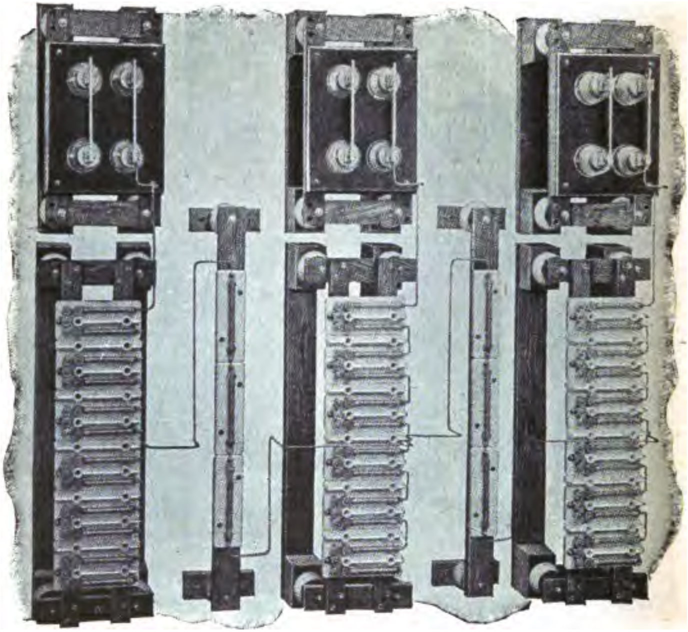


Fig. 327. 13,000 Volt, Three-Phase Lightning Arrester.

where the lines enter the station. The switches may be furnished either front or back connected, and are mounted on slate bases and provided with heavy corrugated glass insulators for the switch studs. The blades are not

provided with handles, but have holes in the ends to enable them to be operated by a hook mounted on a long wooden handle.

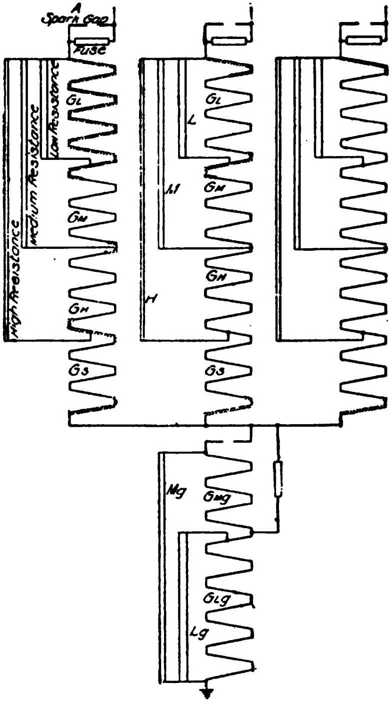


Fig. 328. Diagram of Multigap Graded Shunt Resistance, Three-Phase 33,000 Volt Arrester.

Arresters. In Fig. 327 is shown a 13,000 volt 3-phase arrester with disconnecting switches. This is the older type, but is the kind in most stations.

In Figs. 328 and 329 are given diagrams of the connections of the newer graded shunt resistance type of arrester.

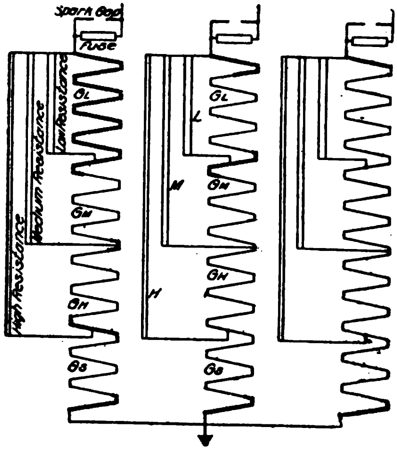


Fig. 329. Arrester Similar to Fig. 328 Arranged for Y System with Grounded Neutral.

In all these note the connections between line and line, besides the line and ground connections.

LESSON 33.

TRANSMISSION LINES, FEEDERS, TROLLEY AND THIRD RAIL.

The transmission line from power house to sub-station or point of feeding into trolley or third rail is usually a pole line.

With high voltages the use of iron poles along the right of way is becoming standard practice. Such a pole is shown in Fig. 330.

From the thickly settled parts of cities and at terminal stations the transmission line should be excluded; but the feeders must be carried underground.

This is done by running insulated cables in ducts. Fig. 331 shows cables supported on side wall of tunnel; Fig. 332 shows ducts for cables in side wall of tunnel or a station; Fig. 333 showing these same ducts arranged under platform of station.

The pole line is of bare wire, copper or aluminum, supported on porcelain or earthen ware insulators.

Fig. 334 shows a 50,000 volt insulator of three separate pieces of porcelain cemented together. It is 11 inches high and weighs 27 pounds. The distance the voltage would have to jump to get to pin or cross arm is 8½ inches.

A 60,000 volt porcelain insulator of four pieces is shown in Fig. 335, while Fig. 336 shows a 75,000 volt three piece porcelain insulator, 15 inches high, weight 40 pounds, with a sparking distance of 11 inches.

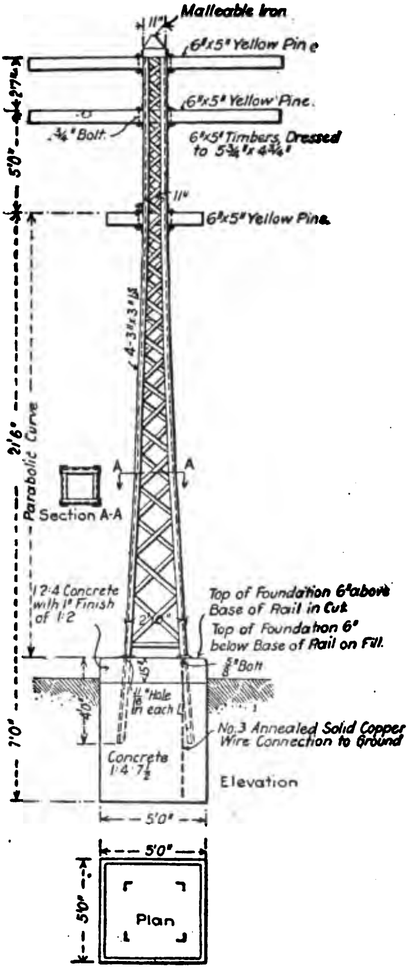


Fig. 330. Transmission Line Pole. New York Central R. R.

When cables are used the voltage is usually lower and glass may be used. Fig. 337 is a glass insulator for cables carrying a pressure of not over 10,000 volts.

Iron pins are used now, as shown in Fig. 338, because the distance the arc must jump is increased by use of a porcelain covered iron pin. Fig. 339 shows the sparking distance with wood pin, and Fig. 340 the increase with porcelain covered iron pin.

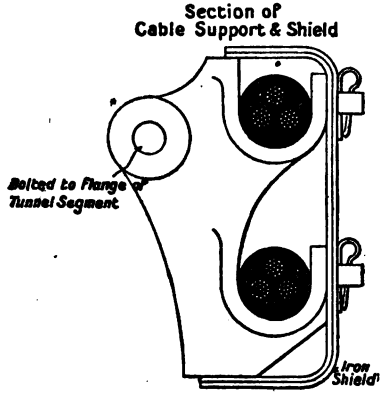


Fig. 331. Cables Supported on Side of Tunnel.

Fig. 341 shows a pin ready to be put straddle of a pole top and Fig. 342 shows an iron pin adapted to bolt on the side of the pole. The porcelain cover has not yet been attached to this pin.

The sparking or arcing distance on an insulator is estimated by imagining a rain storm coming at an angle of 45° and thus conducting the electricity from top umbrella or petticoat to the pin sleeve as in A, Fig. 343.

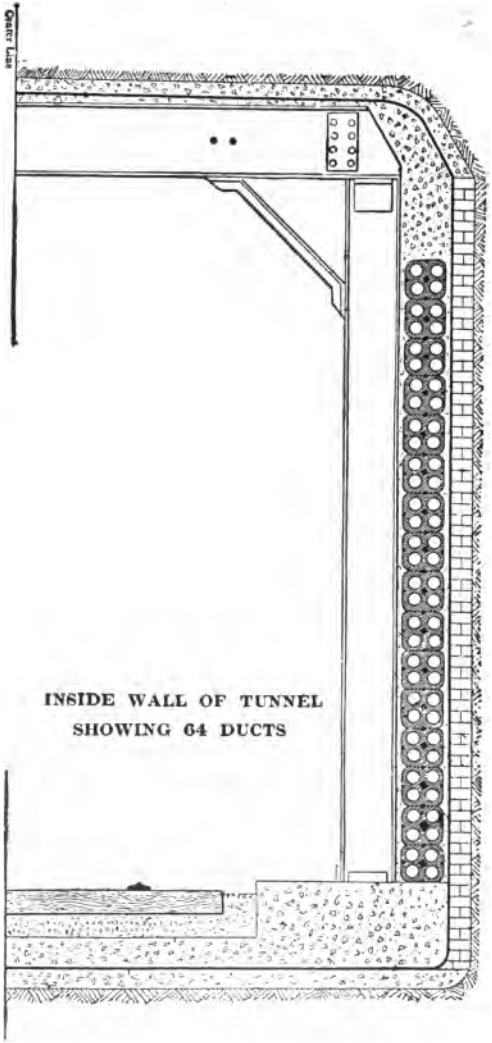


Fig. 332. Ducts Inside of Wall of Tunnel.

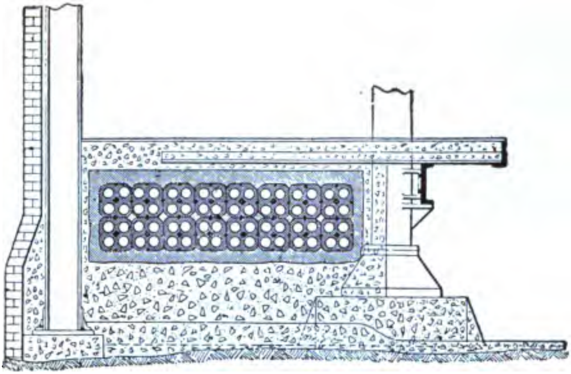


Fig. 333. Ducts Under Passenger Station Platform.

Fig. 334. 50,000 Volt Insulator.

This distance plus the distance B across which the spark would have to jump gives total sparking distance.

When the high tension wires enter a sub-station the arrangement of Fig. 344 is a good one. A large square of slate holds a tube of porcelain, while the shed keeps

Fig. 335. 60,000 Volt Insulator.

whole dry. A sectional view of the porcelain tube is given in Fig. 345.

When the line drops from pole to sub-station a set of strain insulators must be put in to hold the end of line taut. Fig. 346 shows a complete one for moderate pres-

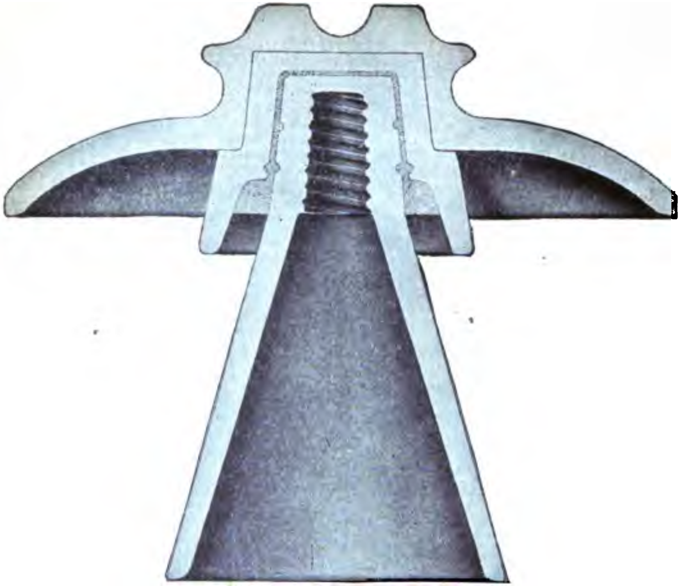


Fig. 336. 75,000 Volt Insulator.

Fig. 337. Glass Cable Insulator, 10,000 Volts.

sures and one end of a triple one when the line is very heavy.

The testing of insulators is shown in Fig. 347, but in addition to this insulators are also tested when complete in their natural position, with regular voltage, while a stream of water, at a downward angle of 45°, is being played on them from a hose.

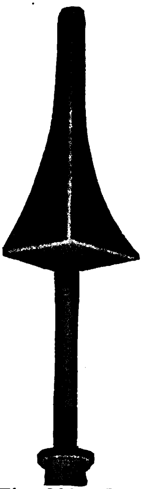


Fig. 338. Iron Pin for Cross Arm.

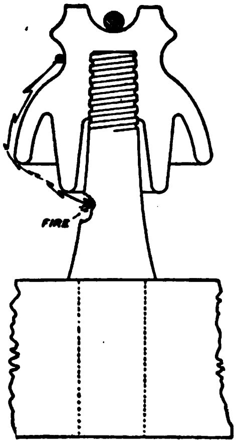


Fig. 339. Arcing When Wood Pin is Used.

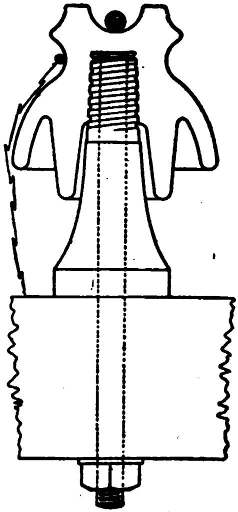


Fig. 340. Sparking Distance When Porcelain Covered Iron Pin is Used.

Overhead Trolley Line.

The old-fashioned single trolley wire with trolley wheel collecting current is unsuitable for high speeds. Its place is taken by the catenary line and bow trolley.

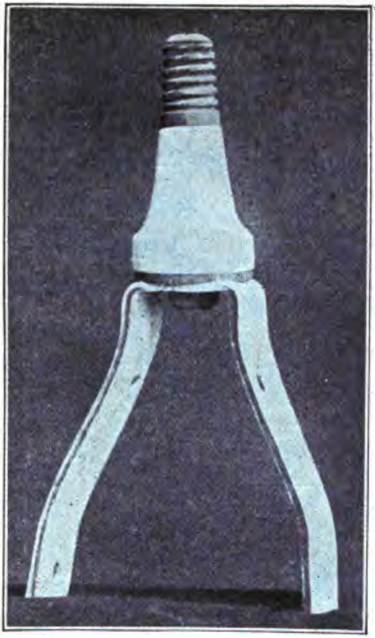
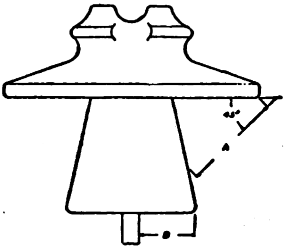


Fig. 341. Pin for Top of Pole.

Fig. 342. Pin for Side of Top of Pole.



A + B = 4½″ = Arcing Distance Wet

Fig. 343. Measurement of Arcing or Sparking Distance.

Figs 348 and 349 will best explain the catenary trolley. Two steel cables are slung between the cross bridges and hang in a natural curve. They are six feet apart at the

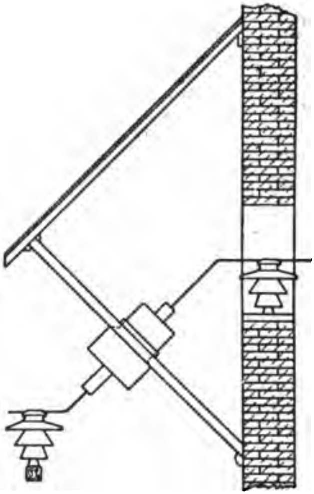


Fig. 344. Bringing In or Taking Out High Tension Line.

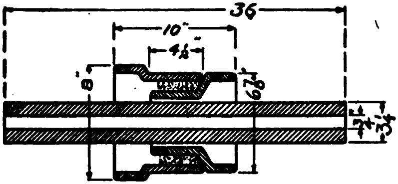


Fig. 345. Sleeve of Fig. 344, also used for Transformer Leads.

ends of the span and six feet lower in center than at ends. A number of triangles of light rods are made up of different sizes. The largest being 6 feet on each side and smallest 1 foot on each side.

These triangles are fastened to the two steel cables at their corners. This brings the cables in near each other at centers of spans. They therefore, starting from the cross bridges or gantries curve in and down.

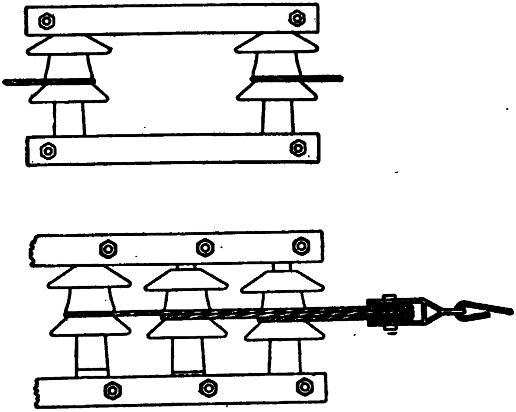


Fig. 346. Single Pin Strain Insulator and one end of a Triple Pin Strain Insulator.

The other corners of the triangles all fall in a straight line 22 feet above the level of track. The copper trolley wire is soldered into the ears which the lower corners of triangles carry.

Fig. 349 shows the curve of the supporting catenary construction and the straight line of the trolley wire.

Fig. 350 shows a gantry with section switches and transformers for operating switches and lights. These gantries occur every two miles. Fig. 351 gives a diagram of such a gantry, also carrying signals. Fig. 352 gives a diagram of a whole span showing curving of cables.

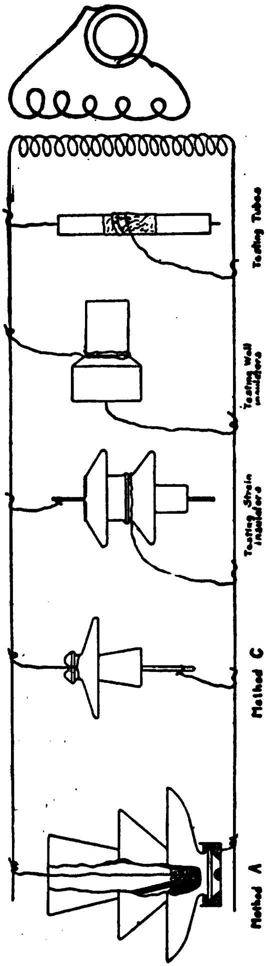


Fig. 347. Method of Testing Insulators.

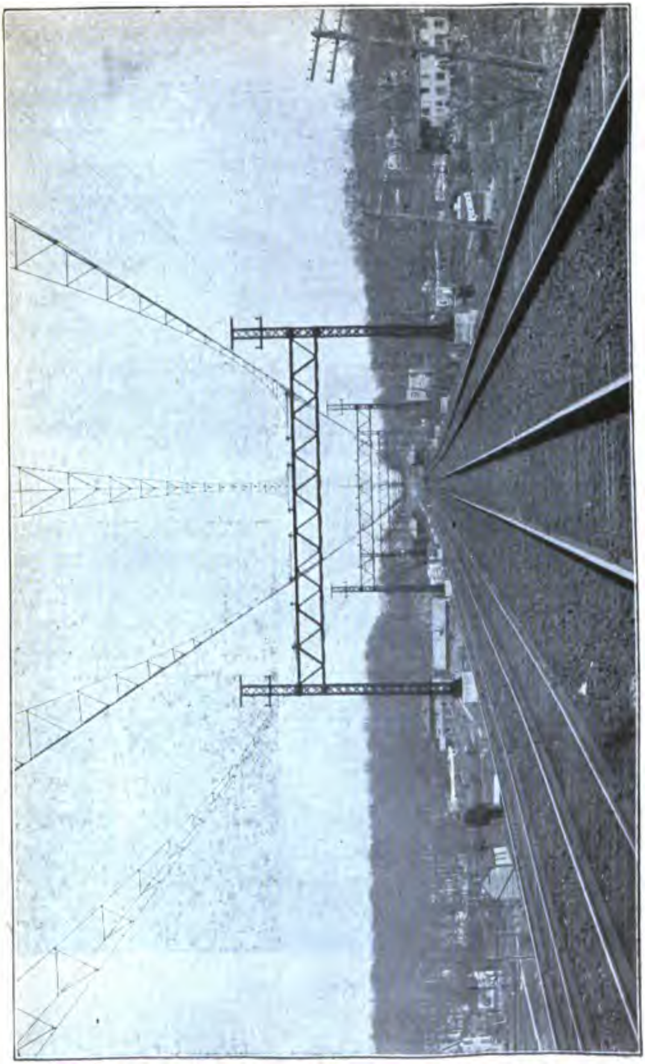


Fig. 348. Four Track Catenary Line, N. Y. N. H. & H. R. R.

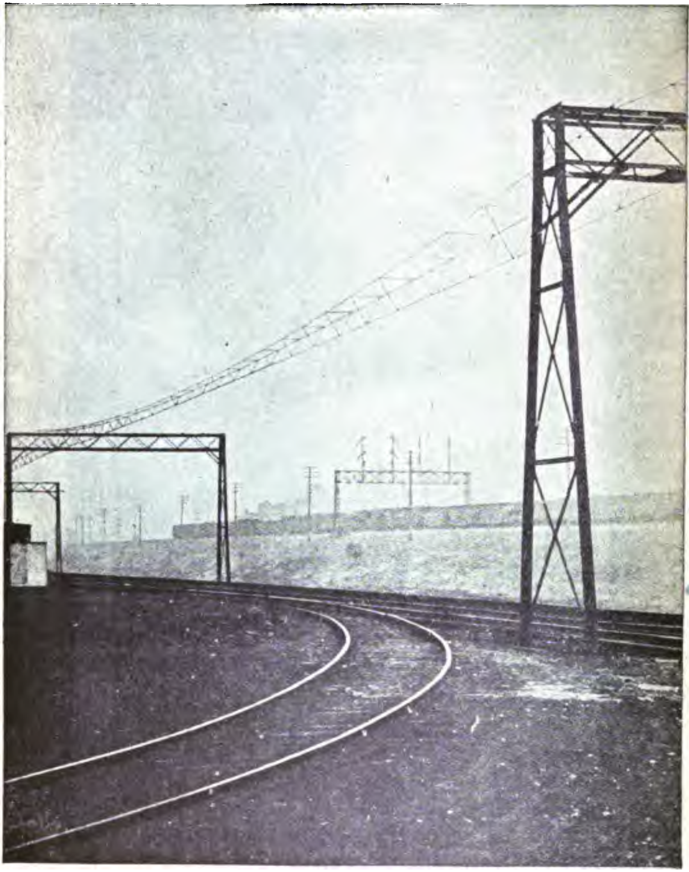


Fig. 349. Catenary Line.

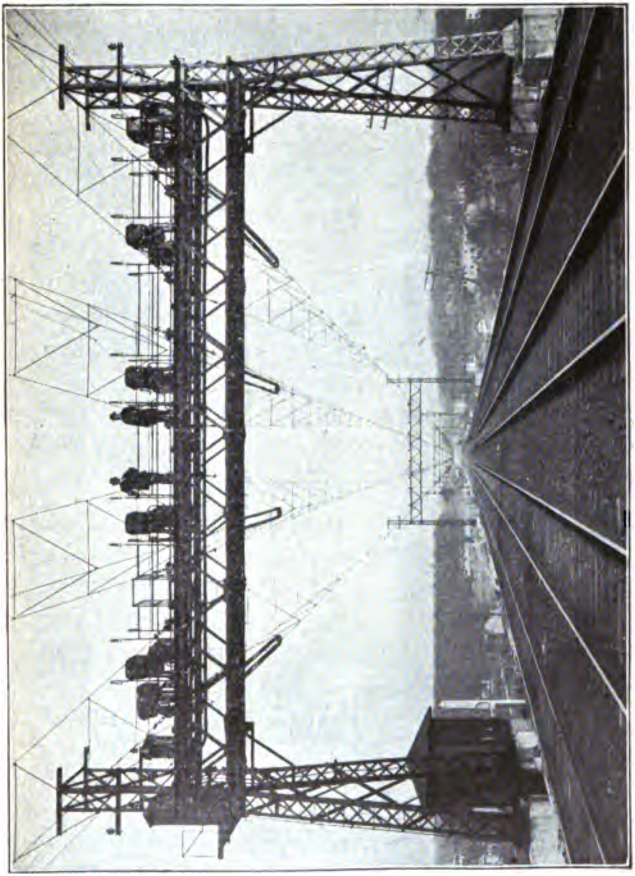


Fig. 350. Gantry with Section Switches, N. Y. N. H. & H. R. R.

Third Rail.

The third rail is usually a 70 pound ordinary steel rail, but lately rails with a certain percentage of copper in them are being used. The rail of the New York Central is copper alloyed.

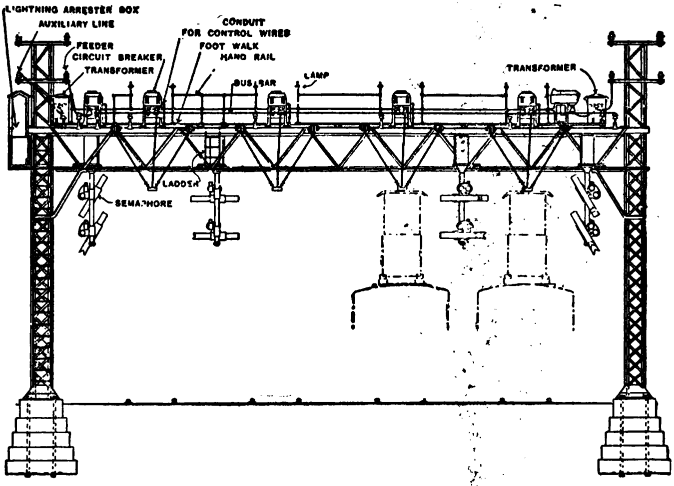


Fig. 351. Gantry with Full Equipment Showing Clearance of Two Locomotives with Trolleys Raised.

Some of the methods of installing the third rail are shown in Fig. 353, while Fig. 354 shows the New York Central under contact type. Heavy snow and sleet storms have shown the under contact to be the most reliable under such conditions.

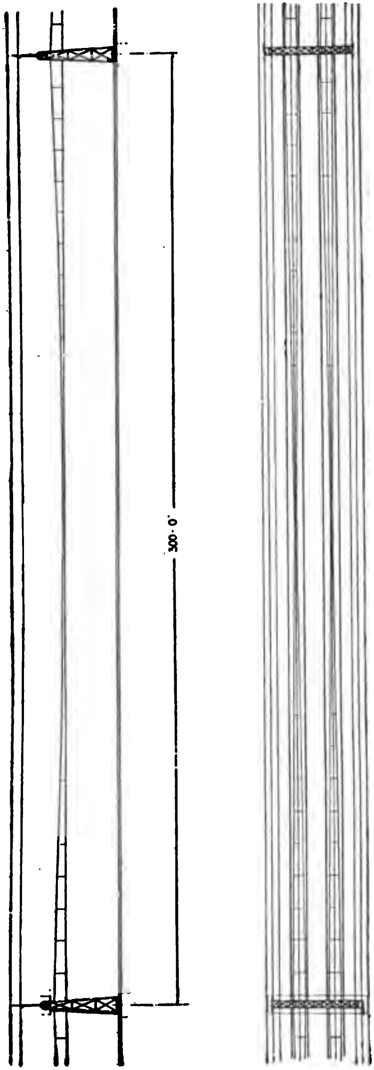


Fig. 352. Side View and Plan of Catenary Span.

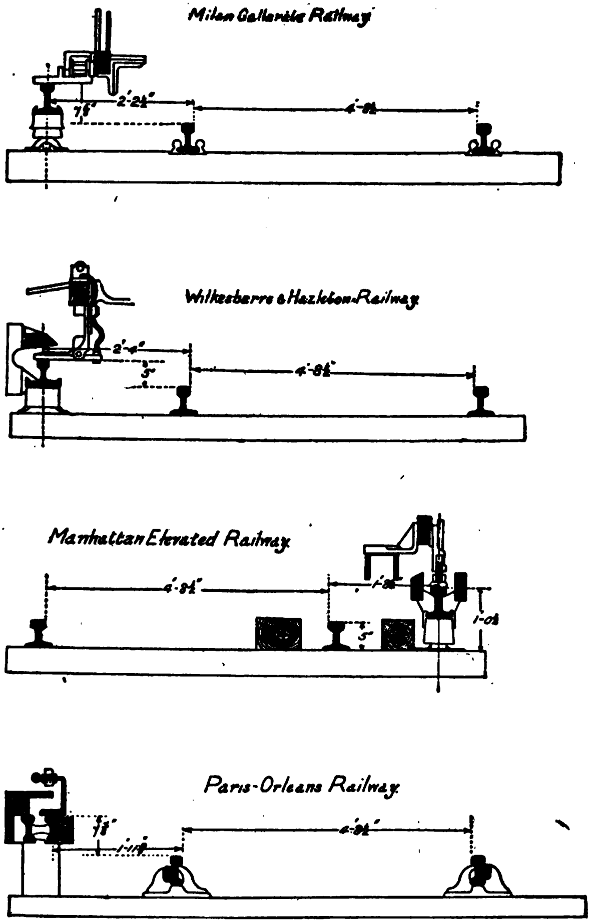


Fig. 353. Third Rail Constructions.

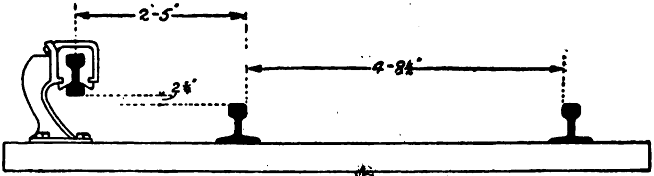


Fig. 354. New York Central Third Rail Construction.

Fig. 355. Third Rail Insulators.

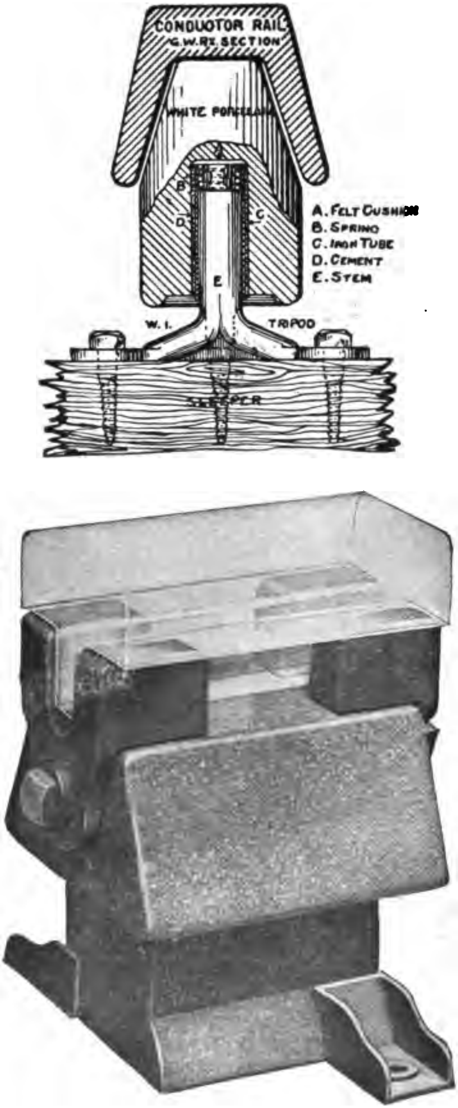


Fig. 356. Two English Third Rails and Insulators.

Insulators for third rail are made of earthen ware and stones such as soap stone. Figs. 355 and 356 show such insulators.

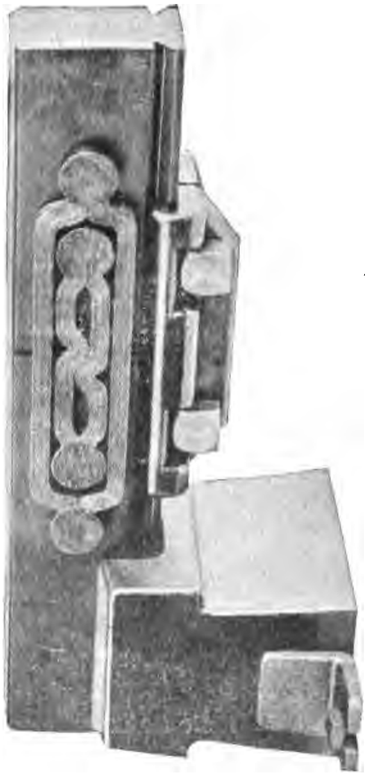


Fig. 357. Third Rail, Insulator, Connector and Riveted Bond.

Bonding.

The resistance of the joints in the third rail or track rails (which return current to power house) is so great that they are shunted by copper conductors called bonds.

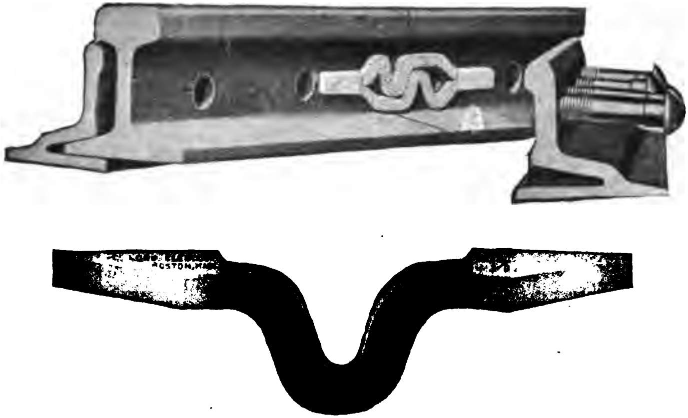


Fig. 358. Bond Protected by Fish-Plate. Soldered to Rail.

Fig. 359. Riveted Bond and Screw Compressor.

Fig. 357 shows a bond whose conductivity is as good as that of the rail itself.

To prevent theft of bonds, for the value of the copper, they are generally installed under the fish plates as in Fig. 358. They may be soldered on rail as in this case or may be inserted in drilled holes and riveted in by screw press. Fig. 359 shows the riveted end and the screw press.

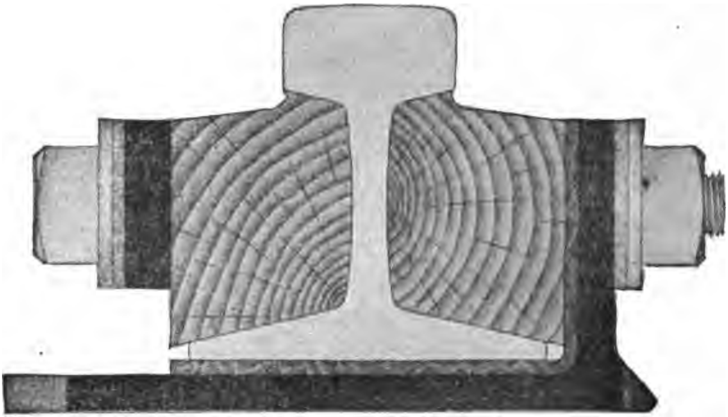


Fig. 360. Insulated Joint.

Insulated Joints.

If for signalling reasons it is desired to cut the track rails into sections, raw hide is placed between ends of rails and wood insulators under fish plates. See Fig. 360.

STEAM OR ELECTRIC TRACTION.

No one disputes the ability of our manufacturers to build electric locomotives light enough to operate upon the present roadbed and bridges and yet possess twenty-five per cent more horse-power than its steam-powered rival.

It is admitted that these electric locomotives will haul heavier trains faster and more economically.

Owing to the huge sums of money necessary to electrify a division it is a question whether there will be sufficient saving to pay interest on and retire the debt incurred by the electrification.

As far as passenger business is concerned, probably the income from its new business (which invariably follows electrification) will be the factor, inducing companies to change over to electricity.

The more frequent service at higher schedule speed has always built up the country feeding the line and induced more traffic.

The number of people who *must* travel is increased by the higher speed (less time spent on road); the number who *want* to travel and *don't* will be reduced. This is because those sections whose distance *in time* was too great will become populated by city workers, and the number of pleasure travelers is increased as soon as the expression, "You can catch a train at any time," becomes prevalent and truthful.

At the present time the obvious solution of the question is to equip those portions of divisions where the *local traffic* is heavy with third rail and run shorter trains (not less than three cars) with motor trucks, at more frequent intervals. The through service will be carried over the same rails by steam.

At large terminal stations the through trains should be hauled to the end of the electric division by the electric locomotives and then forwarded by steam.

It will be the freight business, the expense of which goes by the train mile and its income by the ton mile, which will force trunk lines to electrify whole divisions.

As a consequence of this they will be able to furnish a high speed passenger service at less cost per car-mile than at present. The income being regulated by the passenger-mile, increased earnings will result.

There are two ways of moving a load by electricity, the *car motor* and the *locomotive* system.

For all traffic whose origin and destination is within the limits of the Electrical Division of a railroad, the car motor plan is the cheapest; and the saving in money increases with the frequency of the car's movement.

You pay interest on the cost of a coach, and it brings in no revenue, every moment it stands idle at a terminal, so that when you are paying interest on a motor equipment at the same time it becomes a matter of vital importance that these cars be kept moving.

When the electrical division exchanges through traffic with a steam division and the coaches will be away for long periods, the interest charges on idle motors becomes so great, and the amount of extra equipment, so that plenty of motor cars shall still be at home, grows so

large, that it is cheaper to concentrate a small fraction of these motors on large trucks and use them to haul the trains.

Then when the train is forwarded over the steam division the electric locomotive can lay over 15 or 20 minutes and pull the next incoming train back.

One of the economies of transportation is to make the car miles per motor as large as possible.

For freight, where traffic is interchanged with foreign roads, motor equipment on the cars is out of the question. The large portion of its life spent on sidings and in terminals makes it very doubtful whether car motors would ever pay.

For hauling freight over electric divisions some people figure that steam will do it better. I believe every one sees that long freight trains with as high a speed as is consistent with coal economy is the thing to be desired. With steam this means 12 to 15 M. P. H.

The weight of the locomotive is limited by the strength of bridges and wear and tear upon the road bed. An electric locomotive can be built weighing the same as a steam freight locomotive with 25 per cent more hauling power.

It seems then that the proper way to handle freight in an electric zone is by electric locomotives at a higher speed and less cost per ton mile.

All heavy pusher work on long steep grades would be done more economically by electric locomotives.

A road will handle its suburban business with coaches having motors in the trucks and all through traffic with electric locomotives.

The result of the electrical equipment will be several great economies:

1. In order to haul a train a steam locomotive must be made ready at an expense for labor and coal.

The new locomotive is made ready by closing one switch.

2. Burning coal in many small inefficient fireboxes means a large coal bill per ton mile of traffic moved.

Using cheaper coal in a power-house with more efficient furnaces, a gentler draft and mechanical stokers results in a great saving in coal bills.

3. A steam locomotive standing in a station or in the yard at a terminal after a run, is burning coal with no return.

The instant an electric locomotive stops, the flow of current ceases, and the moment a run is over the expense for coal drops to almost nothing. There is coal burning at the power station, but this coal is for the average load and very little of it is chargeable against an electric locomotive.

4. When a delayed locomotive attempts to make up time, coal is burned at a more rapid rate and steam is used with a longer cut-off; both of which are expensive operations.

The normal operation of an electric locomotive does not utilize the full power of the motors, and when behind schedule the full power is used *without any appreciable change in the efficiency.*

5. The total expense for two power houses, eight substations, thirty locomotives and the third rail is greater than for thirty steam locomotives, but the saving in operating expenses and maintenance of way goes each month to pay the fixed charges of the plant and there is something left over to pay off the debt incurred when installing the electrification.

It is a mistake to think that the horse power of these two power houses must be the sum of the horse power of the thirty steam locomotives they are designed to replace, for all these locomotives are not running at once. The power house only has to take care of the power required for the maximum number of trains running at the same time. This information taken from a train diagram usually results in about 25 per cent of the horse power being installed for service, with some extra for reserve.

6. For the same traffic fewer electric locomotives will be needed.

The average month of a locomotive's life is made up of pulling trains 30 per cent of the time, loafing around under steam waiting for transportation department 50 per cent, under care of motive power department 20 per cent, and a little "soldiering" out on the road.

An electric locomotive is built with an idea of giving almost continuous service. They will tax the ingenuity of the transportation department to find enough work for them to do.

7. A moderate percentage of the expansive force of the steam cannot be used, for the connecting rod would tear the crank pins out. The exhaust is closed ahead of time to avoid this, and the power of engine reduced. A very annoying feature of the steam locomotive is its persistent effort to drive the rails down to China and the seat of the engineer's overalls upwards, due to the flinging effect of any unbalance in the parallel rods and crank pins.

The electric locomotive with its purely rotative motion is very easy on the track, and saves many dollars of expense.

Selection of Equipment.

The type of motors being fixed upon, the actual horse power to be installed on locomotives or cars is determined by consideration of:

1. Schedule speed.
2. Number of miles between stops.
3. Rate of acceleration.
4. Maximum speed.
5. Weight of trains.
6. Grades and curves of track.

The New York Central demanded for its through traffic a locomotive which must be capable of running from Grand Central Station to Croton (34) miles hauling a total train weight of 435 tons in 44 minutes without a stop. To attain on a tangent track with this train a speed of not less than 60 M. P. H. Speed in excess of 65 M. P. H. under these conditions not desired.

To be able to pull a train of 875 tons, making same schedule speed as is at present made with steam locomotives.

Let us ourselves roughly design a locomotive and see how things turn out.

Required the weight and horse-power of an electric locomotive capable of hauling itself and 8 cars of 65 tons each up a 1½% grade at 50 M. P. H., at the same time rounding a curve of 2 degrees; also capable of starting this train from a station on a tangent and level track, in a less time than the present steam locomotives.

To haul a train we must overcome the friction in journal boxes and between wheels and rails; the air resistance and the side thrust of curves. We must apply

enough power to actually lift the train against the force of gravity up any grades.

For every 1% of grade it takes 20 lbs. to pull 1 ton up it. Every 1° of curvature requires 0.7 lbs. per ton to draw train around. These figures are in addition to the pull required for the train friction and air resistance at the particular speed in question.

1% grade needs 20 pounds per ton.
1° curve needs 0.7 pounds per ton.
50 M. P. H. needs 13 pounds per ton.

Hence for our conditions we need

For grade	$1\frac{1}{2} \times 20 = 30.0$	lbs. per ton.
For curve	$2 \times 0.7 = 1.5$	lbs. per ton.
For speed	$= 13$	lbs. per ton.
Total	44.5	lbs. per ton.

8 cars at 65 tons=520 tons.

The pull required at the draw bar of the locomotive will be $44.5 \times 520 = 24{,}000$ lbs. draw bar pull.

The locomotive must brace its feet (drivers) against the road bed (rails), and, having no hoofs to dig in, must develop its grip by pure friction. Usually steel tires against steel rails grip with only ¼ the weight upon them. Figuring on the safe side, call this 1/5, and we have the weight of the locomotive *resting on the drivers,* which must be 5 times the draw bar pull.

This calls for 60 tons on the drivers, but since probably ¼ the total weight of the locomotive will rest on the trucks, the total weight will be about 80 tons, in order to get sufficient *adhesion* to pull the load.

This 80 tons will need 80×45 or 3,600 lbs. to propel

itself. The *tractive force* to be exerted at the rail head will be 24,000+3,600 or 28,000 lbs. in order to haul the total train weight of 520+80=600 tons. There will be 24,000 lbs. draw bar pull exerted to haul the coaches.

The horse power to be installed in this locomotive under the given conditions will be the same as if it were steam driven, *i. e.,* 5 H. P. per ton of train or 5×600=3,000 H. P.

If this locomotive can accelerate a train from a stop on a level, straight track faster than a steam locomotive, it will be satisfactory.

It takes 90 lbs. per ton to increase speed at rate of 1 M. P. H. P. S. on this kind of track. The tractive effort of the locomotive is 28,000 lbs., and dividing by train weight 600 tons gives 46 lbs. per ton to start train on level. 46 is half of 92, so we can accelerate at ½ M. P. H. P. S., which beats a steam locomotive.

The 35 locomotives which the General Electric Company, aided by the American Locomotive Company, built to fit these requirements were found to weigh 100 tons and the power installed was four 550 H. P. motors or 2,200 H. P. in all. These motors are capable of delivering 3,000 H. P. continuously for long periods of time.

Since the conditions of speed, grade, and curve in this problem do not occur very often at the same time, nor even then for long periods, this motor equipment is sufficient.

A view of this locomotive is given in Fig. 361.

The principal dimensions of the locomotive and other data regarding it are given below, and for sake of comparison, the corresponding dimensions of a standard high speed steam locomotive of the Atlantic type are printed in a parallel column.

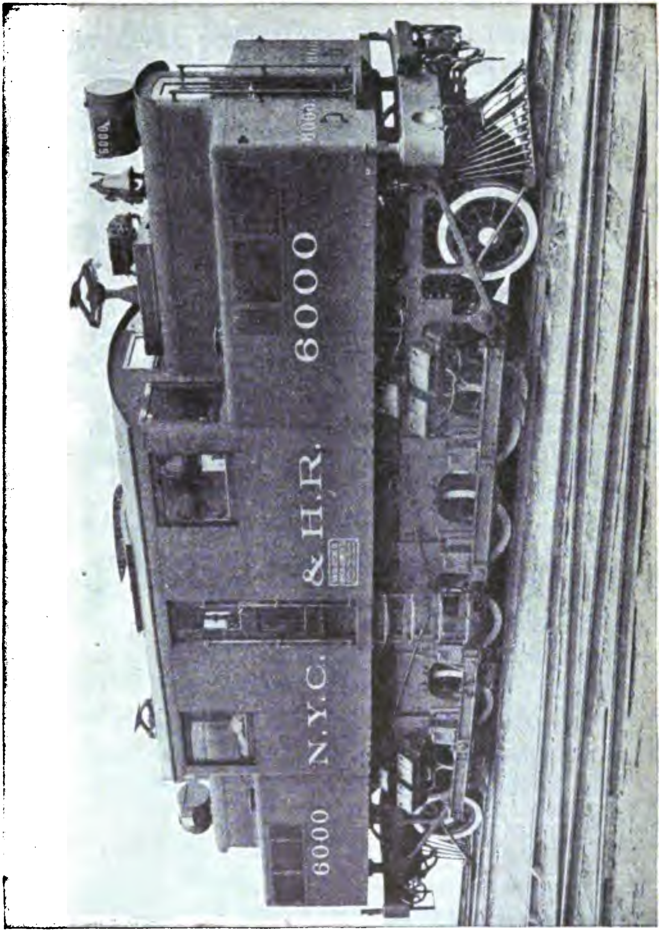


Fig. 361. New York Central Electric Locomotive.

COMPARATIVE DATA OF ELECTRIC AND STEAM LOCOMOTIVE.

ELECTRIC.

No. of driving wheels	8
No. of truck wheels	4
Weight	95 tons.
Weight on drivers	68 "
Wheel base, driving	13 ft.
" " total	27 "
Max. tractive power (draw-bar pull) .	34,000 lbs.
Tractive power per ton engine weight .	330 "
Wheels, driving	44 in.
" engine truck	36 "

STEAM.

No. of driving wheels	4
No. of truck and tender wheels.	14
Weight {Engine, 100 tons; Tender, 61 "} . .	161 tons.
" on drivers	55 "
Wheel base, driving	7 ft.
" " engine	27 ft. 9 in.
" " engine and tender . .	53 ft. 8 in.
Maximum tractive power. . . .	27,500 lbs.
Tractive power per ton engine weight .	171 lbs.
Wheels, driving	79 in.
" engine truck	36 "
" trailing	50 "
" tender	36 "

The following additional data apply to the electric locomotive of the New York Central R. R.:

Length over buffer platforms . .	37 ft.
Extreme width	10 "
Height to top of cab . . .	14 ft. 4 in.
Diameter of driving axles . .	8.5 in.
Normal rated power . . .	2200 H. P.
Maximum power . . .	3000 H. P.
Speed with 500-ton train . . .	60 m.p.h.
Voltage of current supply . .	600
Normal full load current . . .	3050 amperes.
Maximum full load current . .	4300 amperes.
No. of motors	4
Type of motor.	GE—84—A
Rating of each motor . . .	550 H. P.

It is most interesting to note the differences as tabulated below:

	Steam.	Electric.	Difference in favor of electric.
Length over all.........	67 ft. 7¾ ins.	36 ft. 11¼ ins.	30 ft. 8½ ins.
Total weight (including tender for steam locomotive	342,000 lbs.	200,500 lbs.	141,500 lbs.
Concentrated weight on each driving axle.	47,000 lbs.	35,500 lbs.	11,500 lbs.
Revenue bearing load back of locomotive...	256 tons	307.25 tons	51.25 tons
Acceleration M.P.H.P.S. averaging up to 50 M.P.H................	.246	.394	.148
Time required to reach speed of 50 M.P.H.	203 sec.	127 sec.	76 sec.

Fig. 362 shows the comparative distribution of weight for electric and steam locomotives.

The New York Central demanded motor cars which would be able to improve the general suburban traffic conditions, and practically asked for the best equipment which could be furnished them.

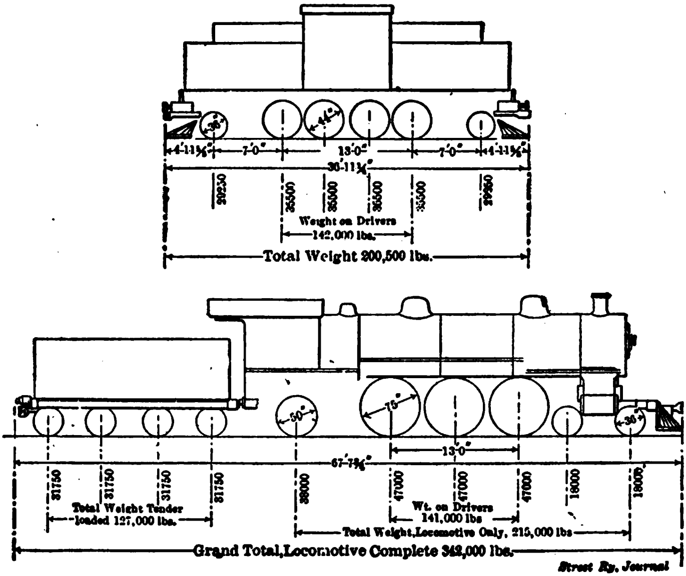
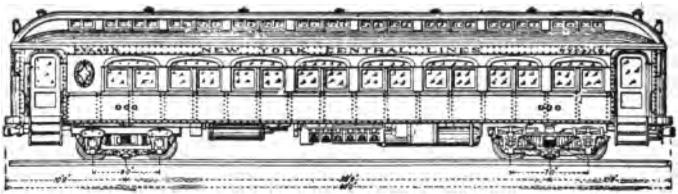


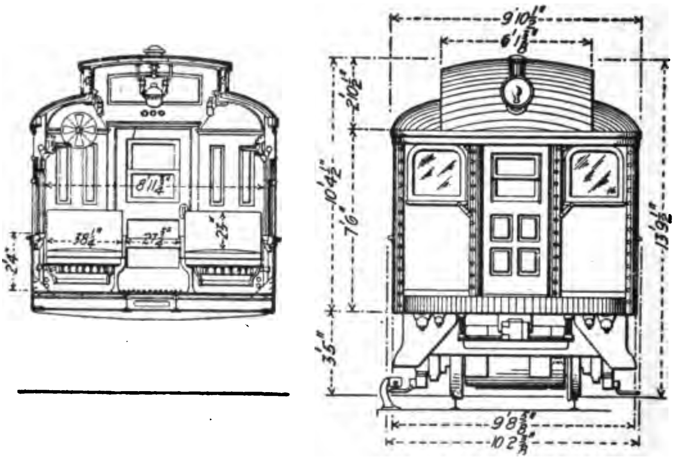
DIAGRAM OF COMPARATIVE WEIGHT DISTRIBUTION
ELECTRIC AND STEAM LOCOMOTIVES
Fig. 362.

This resulted in the building of 125 steel cars (Fig. 363) shown in end view by Fig. 364, which are fitted with the Sprague-General Electric multiple unit system of control, known also as Type M control.



LONGITUDINAL ELEVATION OF NEW YORK CENTRAL STEEL MOTOR CAR

Fig. 363. New York Central Steel Motor Car.



CROSS-SECTION AND END VIEW OF NEW YORK CENTRAL STEEL MOTOR CAR

Fig. 364.

They weigh 51 tons each. Under one end is a M. C. B. trailer truck (with no motors), under other end is a motor truck, both built by American Locomotive Company. The motor truck has two 200 H. P. motors weighing six tons each, geared to wheels by a 2:1 gearing. The trailer wheels are 33 inch, the motor truck wheels 36

inch. There are five tons of electrical equipment on each car besides the motors. They can accelerate at rate of 1.25 miles per hour per second and attain a maximum speed of 52 miles per hour.

A. C. or D. C. TRACTION.

The question as to which is the best A. C. or D. C. systems of traction should not be one of heated argument, as it often is; but rather one of plain presentation of facts, and the drawing of a logical conclusion from them.

For some circumstances an A. C. system is the proper solution of the problem; for others a D. C. system is best; while in still other situations nothing but a combined A. C.-D. C. system will do the work.

The general advantages and disadvantages of each system will be given and a few general conclusions drawn.

A. C. System.

Advantages:

(1) A high voltage may be used allowing use of small feeders and trolley wires.

(2) Distance between power houses may be great, hence only a few are needed. Several large power houses are cheaper to build and operate than a greater number of smaller ones.

(3) The control of speed of train is by "potential control;" this is cheapest method.

Disadvantages:

(1) The trolley must be an over-head system. The conductivity of a third rail for A. C. is low.

(2) A breakage of trolley which might occur (not very likely to happen) would be *very* dangerous to life.

(3) A stiff, non-swaying overhead trolley is as expensive as a third rail.

(4) A. C. motors do not get a train up to speed as quickly as D. C. motors.

(5) To develop same power on A. C. from the same weight of motor, as could be done on D. C. with same weight of material, motors must be cooled by air blast. (This helps to keep dust out.)

(6) Not adapted to freight pusher work as A. C. motors cannot stand still and push.

D. C. Systems.

Straight D. C. or A. C. Transmission.

Advantages: All D. C. systems:

(1) Train gets up to speed very rapidly.

Disadvantages:

(1) Power is delivered to train at 600 volts so feeders and trolley (if used) are large.

Straight D. C. System.

Advantage:

(1) Simple; well understood.

Disadvantages:

(1) Transmission at low voltages makes distance between power houses small.

A. C. Transmission, D. C. Utilization.

Advantages:

(1) Transmission by A. C. high voltage is cheap.
(2) Few power houses required.
(3) D. C. motors used have good acceleration, *i. e.,* get up to speed quickly.

Disadvantages:

(1) Rotary converters must be used.

Conclusions.

It seems from this summary that when getting up to full speed quickly is desired, the D. C. motor should be used. For any economy A. C. transmission should be used.

Let us see if the quick "get away" from stations is of much importance to the operation of a railroad.

The technical name for rate of speed increase is *acceleration.* By this I mean the *increase in speed* in miles per hour which occurs every second from the start from rest until the train reaches its maximum speed.

If a train pulls out of a station and steadily increases its speed, finding itself going at 50 M. P. H.* 203 seconds later, it is evident that *each second* it went 0.246 M. P. H. faster than the previous one, for $0.246 \times 203 = 50$.

If some other train accelerates at the rate of 0.394 M. P. H. per second, it will take 127 seconds to attain a speed of 50 M. P. H.

---

*M. P. H.—Miles per hour.

Acceleration must be high, else the schedule speed for a given maximum speed will be too low, and the time occupied running between stations too long. It cannot be too high, as it would be uncomfortable for passengers, and would require much larger motors, which would not be needed as soon as train was at full speed.

The great virtue of an electrically driven or hauled train is its ability to accelerate rapidly.

For example, let an electric train be capable of accelerating at rate of 0.4 and a steam train at 0.25 M. P. H. P. S.* Suppose both can run at a maximum of 50 M. P. H., but no higher. They start together at a station and run to the next station three miles away.

The steam train takes 200 seconds to arrive at 50 M. P. H. and therefore moves 200 seconds at an *average speed* of 25 M. P. H. or 36.6 F. P. S., and in getting up to speed it passes over 200×36.6 or 7,320 feet. Allowing 2,500 feet for stopping train, there arc 6,020 feet to traverse at 50 M. P. H. or 73.2 F. P. S.

73.2÷6,020 gives 82 seconds.

The stop will take 67 seconds.

Total Time—Steam Train.

200	seconds accelerating over..............	7,320 feet
82	seconds free running over..............	6,020 feet
67	seconds braking over..................	2,500 feet
349	seconds over..........................	15,840 feet

5 min. 49 secs. for 3 miles.

*M.P.H.P.S.—Miles per hour per second.

Total Time—Electric Train.

125	seconds accelerating over..............	4,575 feet
120	seconds free running over..............	8,765 feet
67	seconds braking over..................	2,500 feet
312	seconds	15,840 feet

5 min. 12 secs. for 3 miles.

The difference in time is 37 seconds in favor of the electric train.

In a suburban run of 33 miles with stations every 3 miles, this saving of time is repeated 11 times and the gain in schedule time for the run is 6¾ minutes.

This is assuming what is quite true; that curves, grades, slow downs for signals, stops at stations, will equally affect each train.

When the stations are closer together the saving is even greater. For a two mile interval the log of runs works out as follows:

Total Time—Steam Train.

200	seconds accelerating over..............	7,320 feet
10	seconds free running over..............	740 feet
67	seconds braking over..................	2,500 feet
277	seconds..............................	10,560 feet

4 min. 37 secs. for 2 miles.

Total Time—Electric Train.

125 seconds accelerating over	4,575 feet
48 seconds free running over	3,485 feet
67 seconds braking over	2,500 feet
240 seconds	10,560 feet

4 minutes for 2 miles.

Gain for electric train, 37 seconds.

In a run of 34 miles with two mile station intervals there would be a clear gain of 10½ minutes by electric operation.

To show that this is not a mere paper result, I am showing Fig. 365. This run took place last April on the Mohawk Division of the New York Central, out at Wyatts, just west of Schenectady. The two trains were each of six cars of equal weight. The electric locomotive was No. 6000 and the steam locomotive No. 2797. From the standing start No. 6000 accelerated the more rapidly, and at 1,500 feet from the starting point this photograph was taken. Three and a half minutes after the start No. 6000 was 2,500 feet ahead.

It will thus be seen that for suburban service, where the stations are close together, the acceleration is the most important feature and considerable expense and perhaps even complication may be incurred in order to get good acceleration.

This same argument that an electric motor is better than a steam engine for suburban service holds good to a lesser degree, that a motor driven by D. C. is better for

suburban service than one driven by A. C., because the D. C. motor accelerates the faster.

The advantage of the D. C. motor in this respect begins to be of less consequence as the distance between stations increases. For express train service there is practically no difference in the schedule speeds that they can maintain.

Fig. 365. Acceleration Test between No. 6000 and Pacific No. 2797.

Notice that the longer the runs between stations, the nearer the schedule speed approaches the maximum speed which is attained during free running.

However, the whole story between D. C. and A. C. motors in suburban service is not yet told.

Locomotives making an acceleration of 0.4 or with short trains of 0.5 M. P. H. P. S. are worthless in a

suburban service compared with trains of motor cars making an acceleration of 1.25 M. P. H. P. S., for this three times as great acceleration makes an enormous difference in schedule speed.

With D. C. motors these motor cars can be run in trains and controlled as easily as a single car.

A certain timidity is felt about bringing an 11000 volt A. C. circuit down through a car full of people. About 3,000 volts is all the engineers have screwed up their courage to. But at 3,000 volts the A. C. system has lost all its advantages as regards low cost. It is no cheaper than D. C. It being understood that in A. C. case 11000 volts are reduced in sub-stations to 3000 for trolley, and in D. C. case 11000 volts A. C. are reduced in sub-stations to 600 D. C. for third rail.

Hence we must compare D. C. motor car trains at high acceleration to A. C. locomotive drawn trains at low acceleration.

I think it will be seen that systems using A. C. motors in the present state of the art are not suitable for suburban service on steam roads.

It will be equally obvious that for express service or trunk line operation, the simplicity of the straight A. C. system with 11000 volt trolley and locomotive drawn trains is the better system.

Locomotives or Motor Cars.

The choice between these two depends on whether through or local traffic is to be handled.

The motor car can accelerate at 1.25 M. P. H. P. S. No locomotive could do this, for it could not be made

heavy enough to get the requisite adhesion, without breaking down all the bridges.

Such a locomotive would need 200 tons on its drivers. No existing bridges could stand the strain.

But if we take a 600 ton train of cars, the weight being distributed can be borne. By putting the motors on trucks at one end of each car we get half the weight or 300 tons for adhesion, which is more than is needed.

Motor car trains are then a necessity for suburban traffic.

LESSON 34.

SYSTEMS OF CONTROL.

The control of speed of train is by means of a controller, which throws grids of resistance in or out of motor circuits for D. C. motors; connects motor to different taps of the transformer for A. C. motors; and interchanges the relations of armature and field terminals for either A. C. or D. C. motors.

A control with resistances alone must be used when there is but one motor, as in some mine and factory locomotives. This is called *rheostatic control.*

When there are two motors we may place both in series, giving each motor 250 volts, for half speed; and both in parallel, giving each motor full voltage for full speed.

Acceleration is controlled by use of grid resistances, made of cast iron, shown in Fig. 366. These are cut in the circuit at start by controller and cut out one by one while accelerating to full series; they are then cut into the circuit with the two motors in parallel and again cut out one by one until motors are in full parallel. Thus at the two free running speeds there are no resistances in circuit.

This is called the *series-parallel control.*

When A. C. is used the voltage applied to the motors is varied by connecting more or less of the secondary turns of the step down transformer to the motor. This is called *potential control.*

The series-parallel control is the most familiar to us, for the two K controllers shown in Figs. 367 and 368 are regular equipment on many interurban lines:

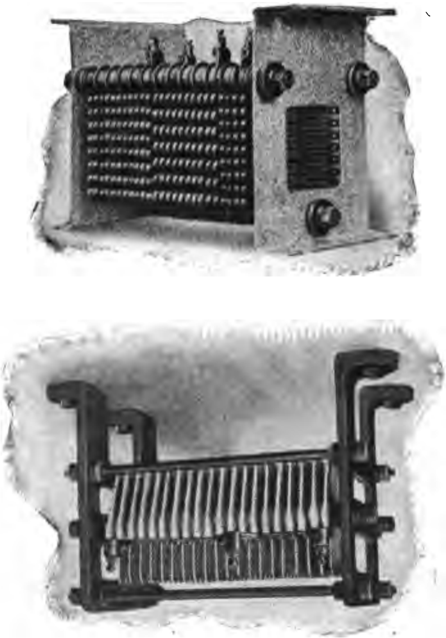


Fig. 366. Cast Iron Grid Resistances.

The letter K designates a controller which never opens the circuit from time motors are started till they are in full parallel or multiple (two names for same thing).

For very heavy equipments the K controller takes the form of Fig. 369, where the cylinder is gear driven.

The letter L used in connection with controllers means

Fig. 367. K Controller.

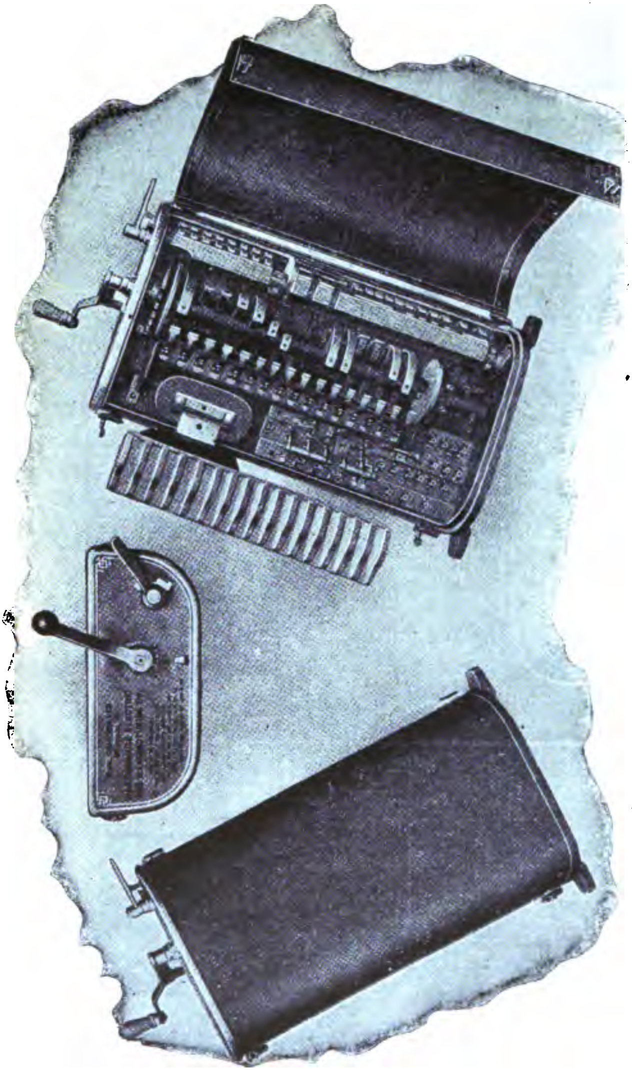


Fig. 368. K Controller.

that when changing motors from full series to parallel with resistance the circuit is momentarily opened. Fig. 370 shows such a controller.

When fitted for electrical braking the letter B is used to designate the type of controller. See Fig. 371.

Fig. 372 shows the electrical connections made by a K controller with two motors.

The notches of a controller are the positions of handle where a spring pawl drops into notches on a plate so as to hold the handle against vibration or slight pressure. The notches are named resistance, running and transition notches.

A resistance notch is one where some resistance is in circuit. These should only be used for very short periods of running. It not only wastes power to use them, but by getting the resistance grid red hot may warp it or might even start a fire.

The running notches are those where there is no resistance in circuit and the motors are in an arrangement suitable for continued use.

A transition notch is where the motors are in some combination so unsuitable for delivering power, that the notch should be passed over quickly.

All notches except transition ones are indicated on top of controller.

Fig. 373 shows connections made by a K controller with four motors.

Fig. 374 shows connections made by an L controller with two motors. The points to be noticed are: The gradual decrease of the resistance* in circuit, it taking

*The decrease of resistance is shown in a novel way by placing more of them in parallel. In diagram the wider the resistance, the lower it is.

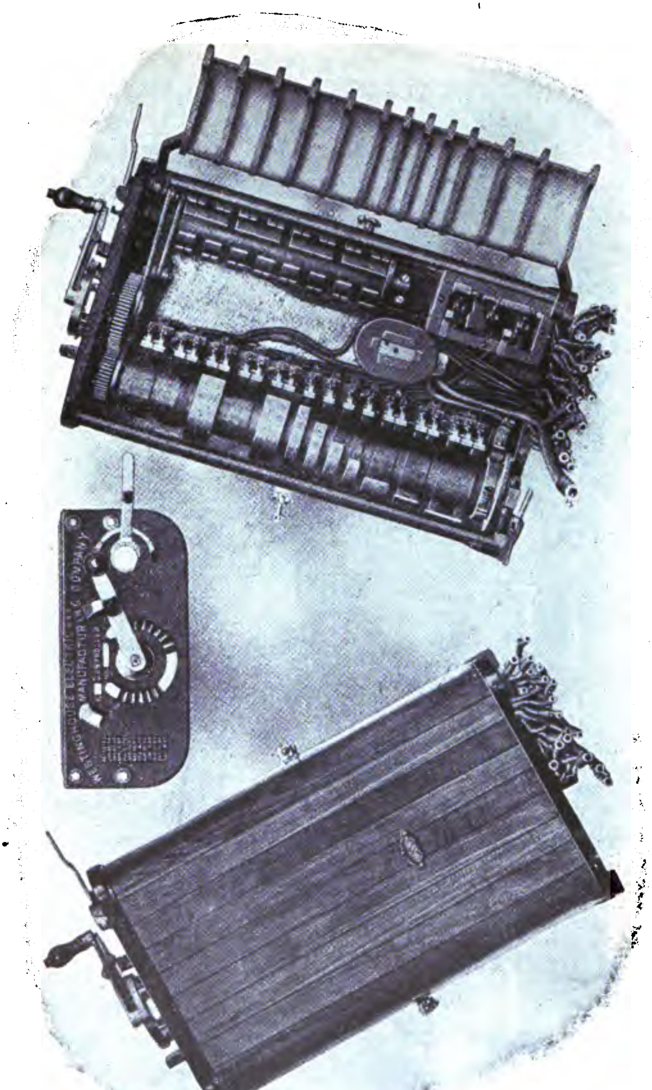


Fig. 369. K-B Controller.

12 notches to get a full series. There are a lot of resistance notches called transition notches simply because there are no marks on top on controller to indicate them Note the opening of circuit at notch 12½.

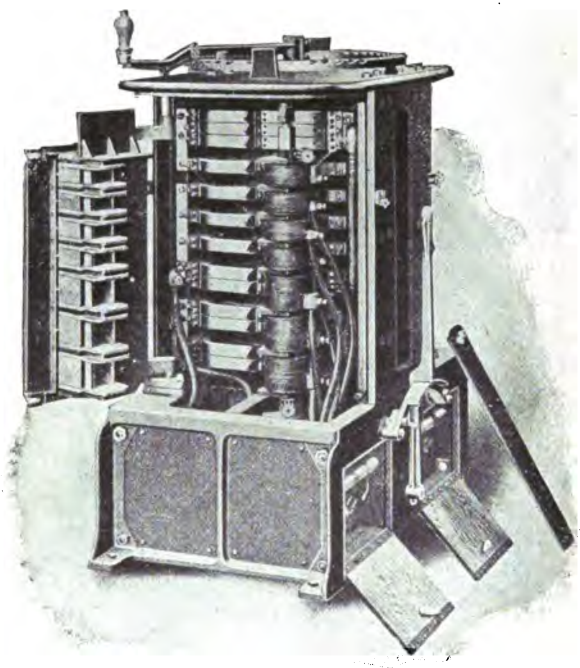


Fig. 370. L Controller.

The student should number the multiple notches up tc 24 himself.

Fig. 375 shows the connections made for electrical braking when two and four motors are used.

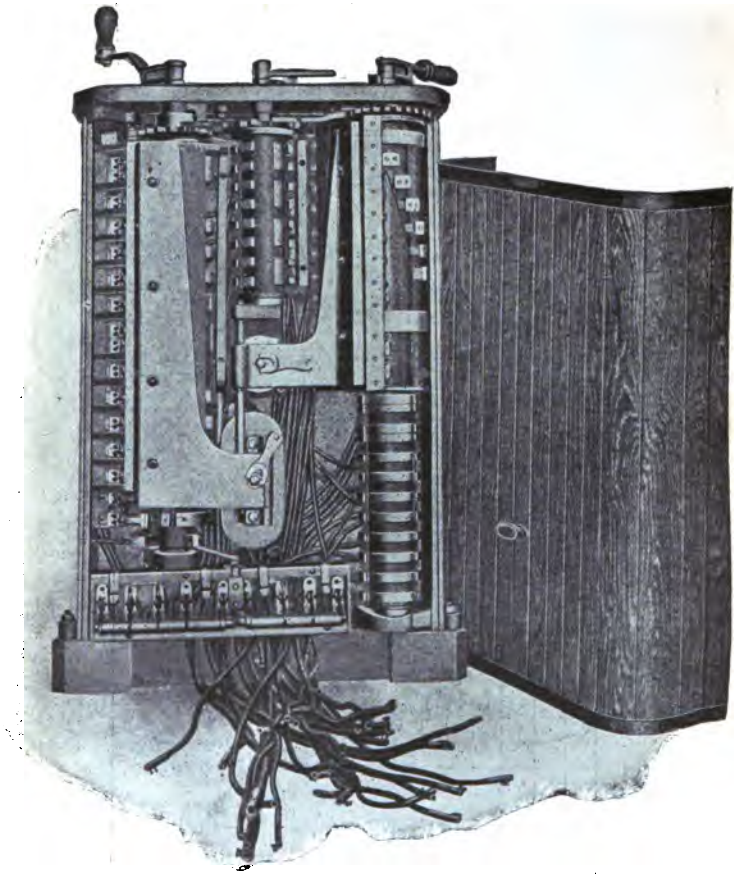


Fig. 371. B Controller.

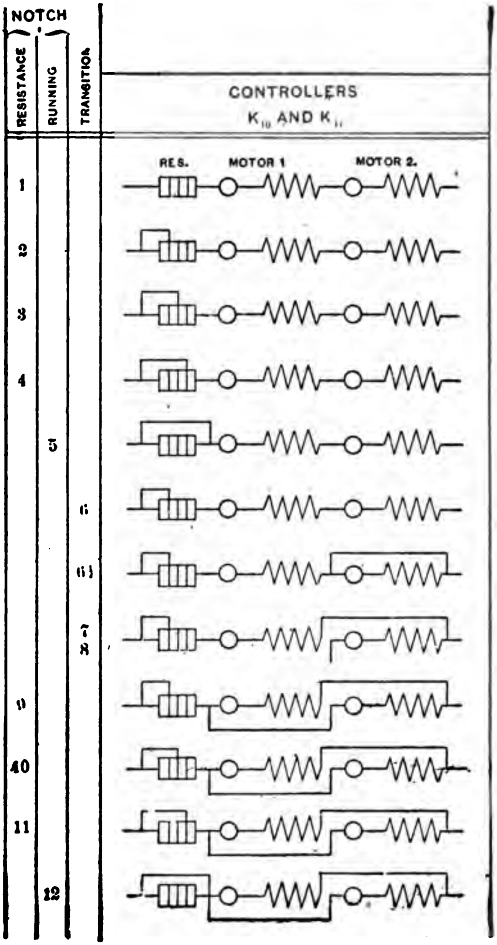


Fig. 372. Scheme of K Control with Two Motors.

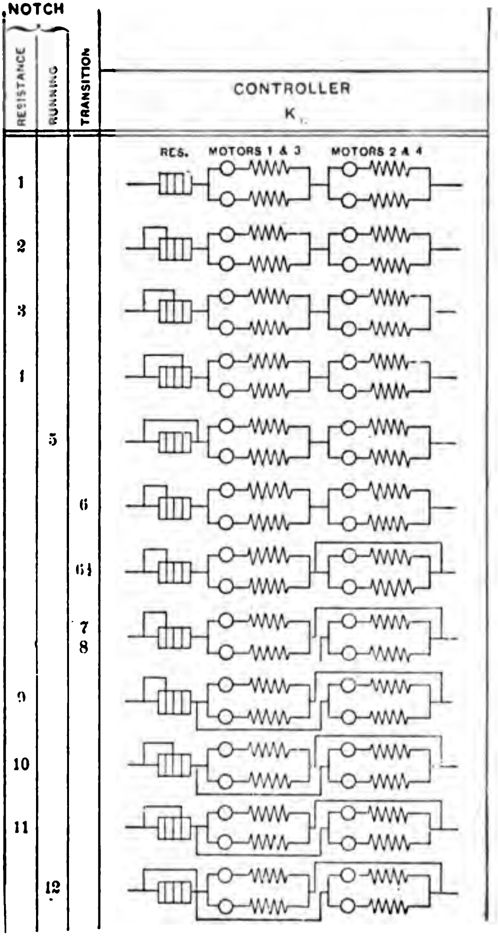


Fig. 373. Scheme of K Control with Four Motors.

Electrical braking uses the motors more than simply running the car, and so they heat more. This means a larger motor for the same schedule speed.

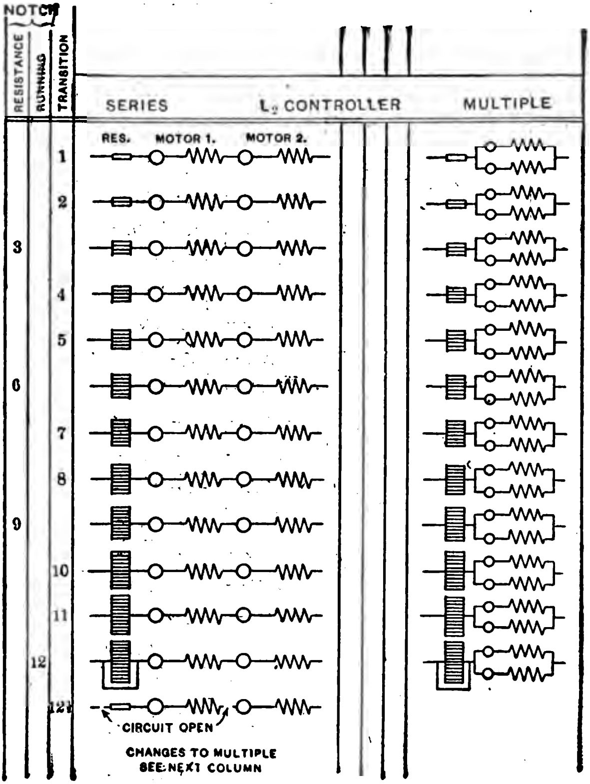


Fig. 374. Scheme of L Control.

In some controllers the movement of the hand is mechanically connected to the cylinder. Such a control is a *manual* control.

In other cases the controller merely arranges contacts which energize circuits to electro-magnetically operated switches called contactors; or electro-magnetic valves

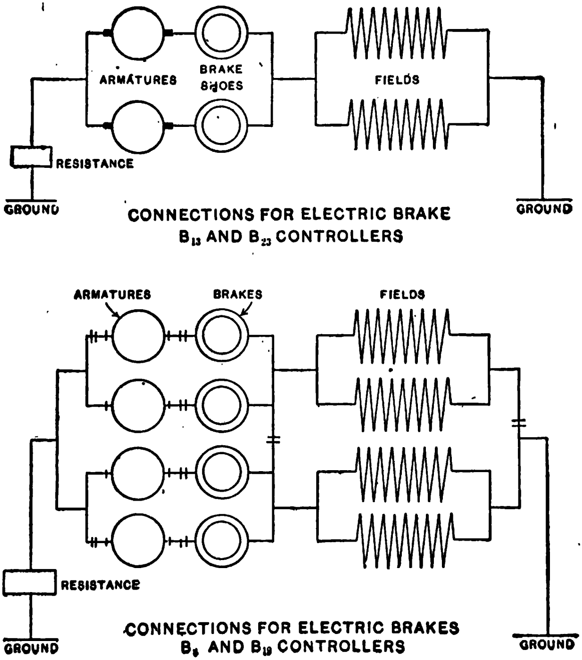


Fig. 375. Scheme of Electrical Braking Connections.

are operated which in turn operate pneumatic cylinders. The push rods from these cylinders open and close the switches. Controllers of this class are called *master controllers.*

LESSON 35.

THE SPRAGUE GENERAL ELECTRIC TYPE M CONTROL.

The Sprague-General Electric Type M Control is designed primarily for the operation of a train of motor and trail cars, coupled in any combination and the whole operated as a single unit from any controller on the train. The system may also be used to advantage on individual equipments and locomotives.

The control apparatus for each motor car may be considered as consisting essentially of a motor controller and a master controller.

The motor controller comprises a set of apparatus (Fig. 376) usually located underneath the car (Fig. 377), which handles directly the power circuits for the motors, connecting them in series and parallel and commutating the starting resistance in series with them. This motor controller is operated electrically, and its operation in establishing the desired motor connections is controlled by the motorman by means of the master controller, Fig. 378, which is similar in construction to the ordinary cylinder controller and is handled in the same manner. Instead of effecting the motor combinations directly, however, this controller merely governs the operation of the motor controller.

The master controller operates a number of electrically operated switches, or "contactors," which close and open the various motor and resistance circuits, and an electrically operated "reverser" that connects the field

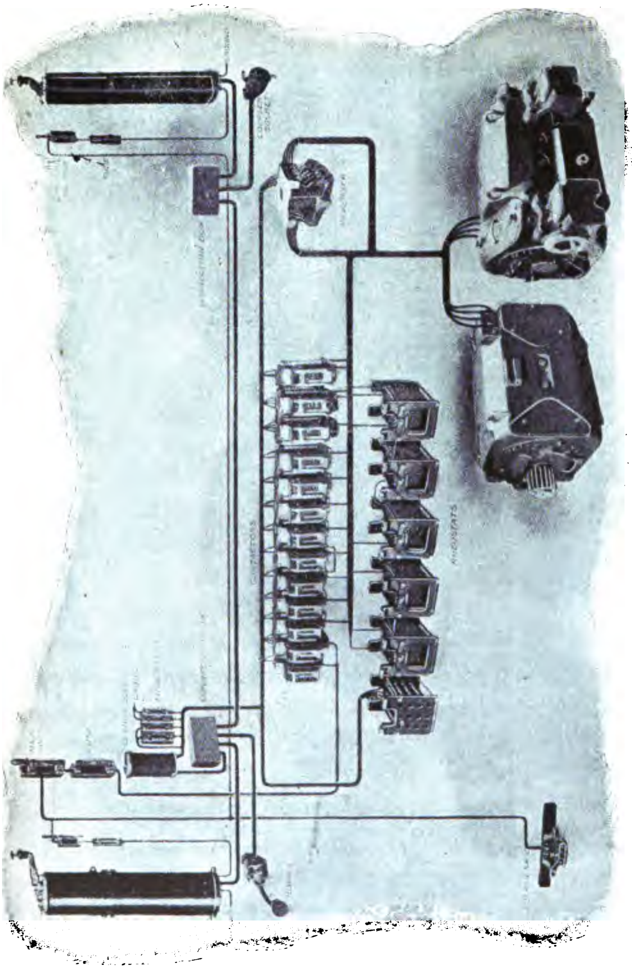


Fig. 376. General View of Apparatus Type M Control.

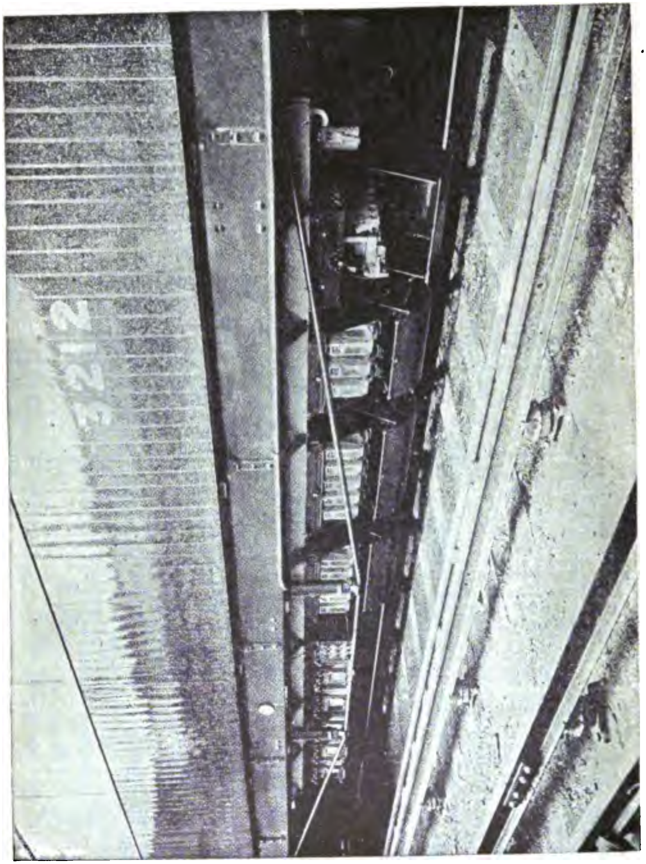


Fig. 377. Arrangement of Control Apparatus Under Car.

and armature leads of the motors to give the desired direction of movement to the car. Both the contactors and reverser are operated by solenoids, the operating current for which is admitted to them by the master controller.

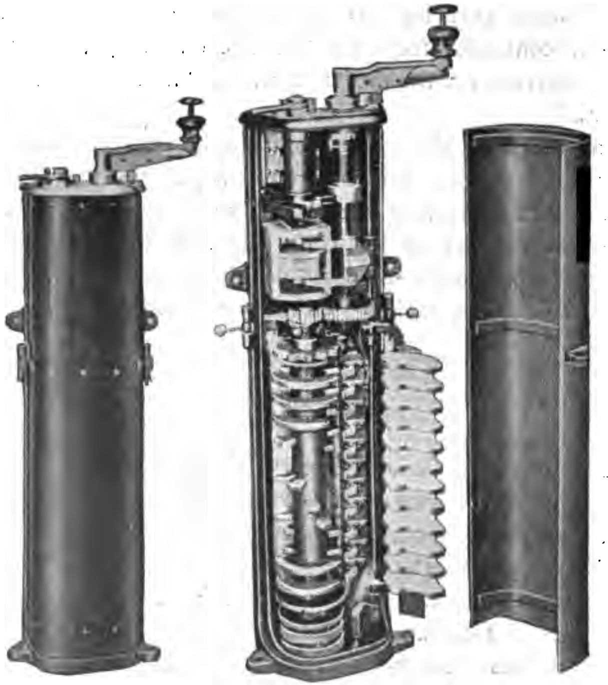


Fig. 378. Master Controller for Sprague-General Electric Control.

Each motor and trail car is equipped with train cable, consisting of nine or ten individually insulated conductors connected to corresponding contacts in coupler sockets located at each end of the car. This train cable is

connected identically on each motor car to the master controller fingers and the contactor and reverser operating coils, and is made continuous throughout the train by couplers between cars, connecting corresponding terminals in the coupler sockets.

All wires carrying current supplied directly from the master controller form the "control circuit"; those carrying current for the motors form the "motor" or "power circuit."

Inasmuch as the motor controller operating coils are connected to this control train line, it will be appreciated that energizing the proper wires by means of any master controller on the train will simultaneously operate corresponding contactors on all the motor cars, and simultaneously establish similar motor connections on all cars.

Advantages.

The Sprague-General Electric Type M Control permits a train of motor cars and trailers to be operated as a single unit from any master controller on the train. If desired, a master controller can be placed on each platform of trail cars, thereby providing for the operation of the train from any platform. With this arrangement, the motorman can be always at the head of the train, regardless of the combination of the cars.

The entire train, equipped with Type M Control, may thus be regarded as a unit; the motorman has the same control over a train that he would have over a single car with the ordinary cylinder controller.

Should the motorman remove his hand from the operating handle of the master controller, the current will

be immediately cut off from the entire train, thus diminishing the danger of accident in case the motorman should suddenly become incapacitated.

The system will operate at any line potential between 300 volts and 600 volts, and the action of all contactors is absolutely reliable and instantaneous.

On heavy equipments the effort of the motorman in operating the master controller is so much less than that required to handle a large cylindrical controller that he can give more attention to the air brakes and other parts of the equipment, especially in cases of emergency.

The approximate total weight per motor car of control equipments, exclusive of supports, is 2,500 pounds for 300 H. P. of motors.

The approximate weight of the apparatus for each trail car, which comprises train cable, coupler sockets and connection boxes, is 100 lbs.

In many cases it will be found advantageous to anticipate the future growth of an interurban road by equipping each motor car with Type M Control. In these cases it will be easy to change from single car to train service whenever warranted by traffic conditions.

The position of the handle on that master controller which the motorman is operating always indicates the position of motor control apparatus on all cars.

Contactors.

The contactors are the means of cutting in and out the various resistances, of making and breaking the main circuit between trolley and motors, and of changing from series to parallel connection.

Each contactor consists of a movable arm carrying a renewable copper tip which makes contact with a similar fixed tip, and a coil for actuating this arm when supplied with current from the master controller. The contactor is so designed that the motor circuit is closed

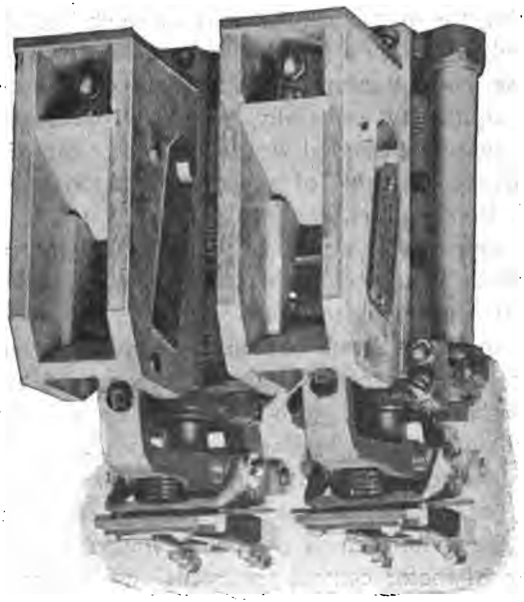


Fig. 379. Contactors with Interlocks.

only when current is flowing through its operating coil; and gravity, assisted by the spring action of the finger, causes the arm to drop and open the circuit immediately, when the control circuit is interrupted. Each contactor has an effective and powerful magnetic blow-out, which

will disrupt the motor circuit under conditions far exceeding normal operation. In closing, the copper tips come together with a wiping action, which cleans and smooths their surfaces.

All contactors in an equipment are practically identical, and the few parts which are subject to burning and wear are so constructed as to be readily replaceable.

In order to save space and eliminate interconnections as much as possible, several contactors are mounted on the same base (Fig. 379). The contactors should preferably be located under the car, and boxes are therefore supplied which facilitate installation, protect the contactors from brake-shoe dust and other foreign material, and provide the necessary insulation. These boxes are built with perforated openings for ventilation, but shields are supplied for closing these perforations whenever desirable.

Reverser.

The general design of the reverser (Fig. 380) is somewhat similar to the ordinary cylindrical motor reversing switch with the addition of electro-magnets for throwing it to either forward or reverse position. In general construction, the operating coils are similar to those used on the contactors, but in order to secure absolute reliability of action in throwing, the coil is given full line potential. The reverser is provided with small fingers for handling control circuit connections, and when it throws, the operating coil is disconnected from ground and is placed in series with a set of contactor coils, thus cutting the operating current down to a safe running value. These coils are protected by a fuse, which will

immediately open the circuit if the reverser fails to throw. If the position of the reverser does not correspond to the direction of movement indicated by the reverse handle on the master controller, the motors on that car cannot take current. While the motors are taking current the operating coil is energized, and the electrical circuits are interlocked to prevent possibility of throwing.

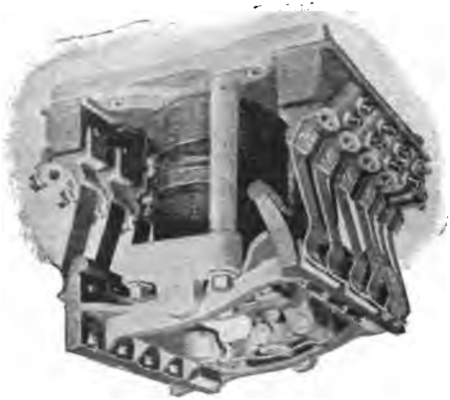


Fig. 380. Reverser on Motor Cars.

Master Controller.

The master controller (Fig. 378) is considerably smaller than the ordinary street car controller, but is similar in appearance and method of operation. Separate power and reverse handles are provided, as experience has led to the adoption of this arrangement in preference to providing for the movement of a single handle in opposite directions.

An automatic, safety, open-circuiting device is provided whereby, in case the motorman removes his hand from the master controller handle, the control circuit will be automatically opened by means of auxiliary contacts in the controller, which are operated by a spring when the button in the handle is released. This device is entirely separate and distinct in its action from that of the main cylinder. Moving the reverse handle either forward or backward makes connections for throwing the reverser to either forward or backward position. The handle can be removed only in the intermediate or off position. As the power handle is mechanically locked against movement when the reverse handle is removed, it is necessary for the motorman to carry only this handle when leaving the car.

When the master controller is thrown off, both line and ground connections are severed from the operating coils of important contactors, and none of the wires in the train cables are alive.

The current carried by the master controller is about 2.5 amperes for each equipment of 400 H. P. or less. This small current carrying capacity permits a compact construction, and the controller weighs only 130 lbs.

Master Controller Switch.

A small enclosed switch with magnetic blow-out is used to cut off current from each master controller, and is supplied with a small cartridge fuse enclosed in the same box. When this switch is open all current is cut off from that particular master controller which it protects.

Control Cable.

A special flexible cable, made up of different colored individually insulated conductors, is used for the train cable and, whenever possible, to make connections between the various pieces of control apparatus.

Connection Box.

Connection boxes are provided for connecting the control circuit cables at junction points without splicing, and small copper terminals are supplied for attaching to the ends of the individual conductors.

Control Couplers.

The master control cables of each car terminate in sockets and are interconnected by means of a short section of similar flexible cable fitted with plugs. Each socket contains a number of insulated, metallic contacts connected to the train wires, and the terminal plugs of the coupler contain corresponding contacts. The parts subject to wear are readily replaceable.

All coupler sockets are provided with spring catches which hold the plugs in contact under normal conditions, and permit them to automatically release in case two cars separate.

Control Cut-Out Switch.

This is a switch, usually nine-point, installed on each motor car and is used to disconnect the operating coils of the contactors and reverser from the train cable, and hence render them inoperative.

Control Fuses.

On each car several small enclosed fuses are placed in the control circuit at such points as to effectively protect the apparatus.

Fig. 381. Control Rheostat.

Control Rheostat.

While starting car, tubes of a high resistance rheostat are connected in series with the contactor coils to cut down the operating current to a value approximating that for the running positions of the controller. This rheostat is enclosed in a sheet iron case for protection. Fig. 381.

CONNECTIONS OF SPRAGUE-GENERAL ELECTRIC TYPE M CONTROL SYSTEM

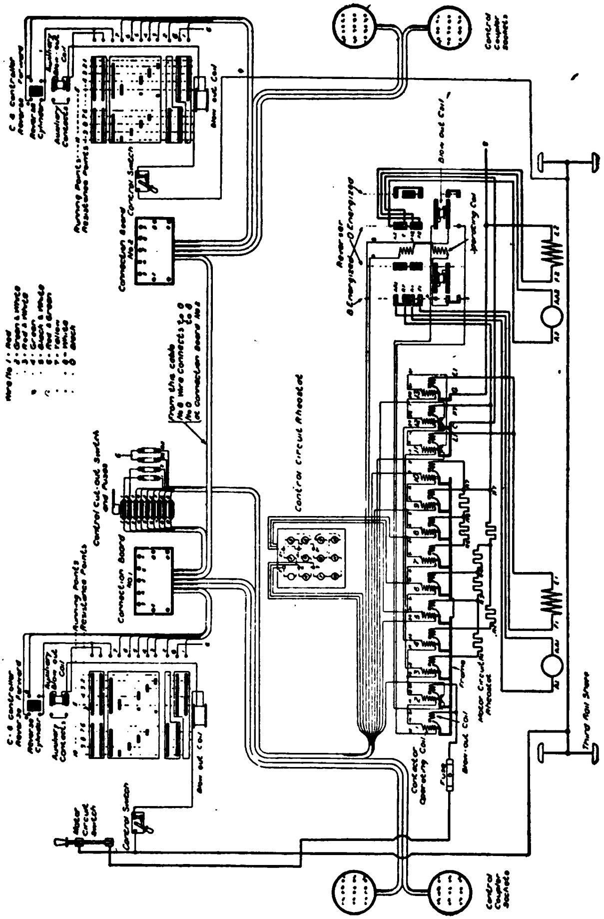


Fig. 382.

Circuits.

The motor circuit is local to each car, and on the first point the current on entering from the trolley or third rail shoe passes through the following pieces of apparatus in the order named: main switch and fuse, contactors, resistances, reverser, motors; thence to ground.

In the control circuit, the course of the current from trolley to ground is through the master controller switch and fuse, the master controller, connection box, to the cut-out switch. From the cut-out switch the current passes through the control cable to the operating coils of the reverser and contactors, and thence through fuses to ground.

Automatic Features.

The apparatus described is used with the standard equipment for hand control. If automatic features are desired they can be installed. See Lesson 36.

Wiring Diagram.

A diagram of the wiring of apparatus shown in Fig. 376 will be found in Fig. 382.

LESSON 36.

AUTOMATIC ACCELERATION.

In some systems of control the closing and opening of switches is in unison with the movement of the controller handle.

This has two disadvantages. In the first place the motorman by a too rapid movement of the handle gives the motor current too fast, which results in the car starting too fast, causing a waste of current and discomfort to passengers. Secondly, the motorman may through caution start train too slowly and thus spoil the schedule speed.

To remedy the first and most important, starting too fast, *controlled acceleration* was adopted. Devices called "motoneers," "auto motors," etc., were placed on controllers. All these are friction or rachet and pawl affairs which bind when handle is moved too fast, or which compel a stop at each controller point.

Some controllers, as the New York Central locomotives, have a friction clutch operated by the main current. When engineer moves controller handle too fast, too much current flows to motors. This excessive current sets the friction clutch so that handle can be moved no further till current falls to its proper value.

The New York Subway controllers (Fig. 383) have handle geared to the main cylinder but the motion is transmitted from handle to gears through a heavy spiral spring. The handle may be thrown all the way round,

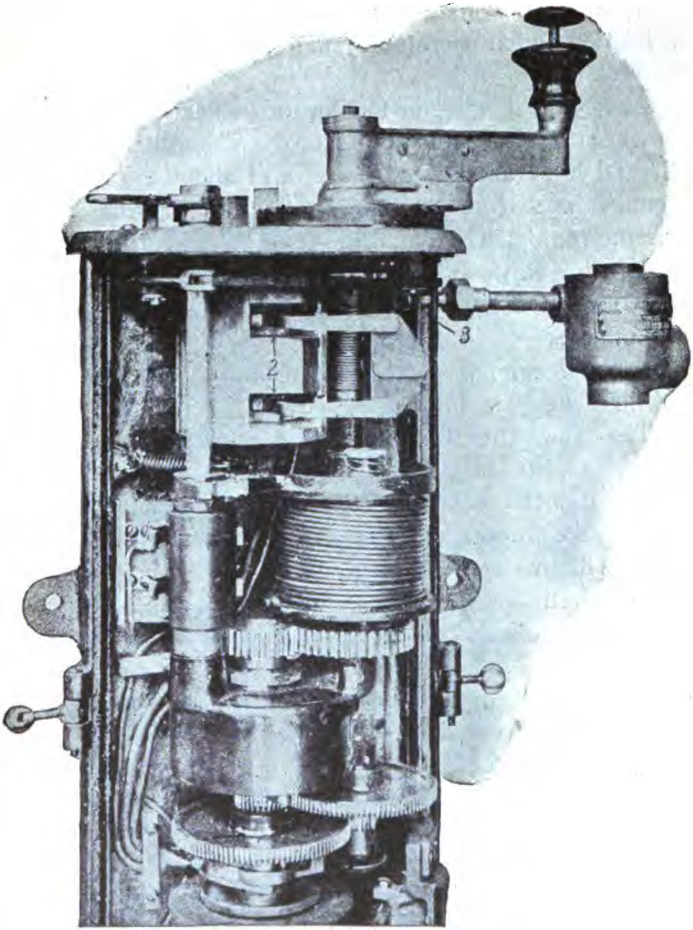


Fig. 383. Controller Used with New York Subway Equipments.

which winding the spring, causes it to turn the main cylinder. The speed of this main drum is regulated by a friction clutch operated by the current passing through motors.

At 1 in Fig. 383 is the button which must be held down at all times when motors are receiving power. Should it be allowed to rise it will allow the auxiliary contacts at 2 to make upper contact, thus cutting power off the motors while at same time through the medium of a pilot valve at 3 (hardly visible in figure) and a brake valve at 4, giving the emergency application of air brakes.

When handle is at "Off" the button may be let up without applying brakes.

The New York Central automatic acceleration is not an attachment to the controller, nor is it a controlled acceleration as in the Subway type. It is a true automatic acceleration and the whole system of control is built with that end in view.

The controller is shown in Fig. 493.

The controller when on second and fourth notch ahead or on second notch reverse, has two wires in circuit called the *pick up* and *hold up* wires. The duty of the pick up wire is to close contactors, the contactor is then held up by the hold up wire.

Fig. 384 shows how the automatic acceleration takes place.

The power circuit comes from the trolley connection through the resistances and through the coil of the relay R and thence to the motors. E is the contact which the relay opens and closes. The coil which operates the contactor is marked M. The rod which pulls up the jaw of the contactors passes up through the contactor

coil M and carries four plates A, B, C and D. A series of contacts as shown by the little black circles are arranged as in the diagram.

The two control wires 1 and 2, are connected to trolley and energized through the controller. W1 is the *pick up* and W2 is the *hold up* wire.

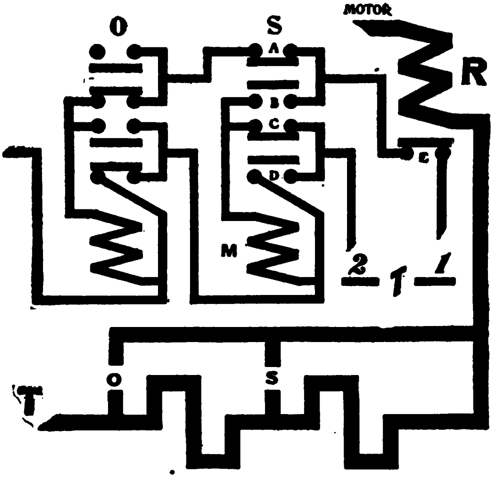


Fig. 384. Diagram of Wiring and Interlocks for Automatic Acceleration.

The contactor marked S is shut and the one marked O is open.

By reference to O you will understand how S was closed, in the following manner.

Current comes through W1 and passes through the B contacts down through the coil M and along W2 to the next contactor.

The contactor now closes and a reference to S will show how it remains closed.

The closing pushed the plates up and out of contact at B and D; and into contact with A and C. The current from W1 now passes through the A contacts and on to the next contactor, where it "picks it up." The coil M is now in the W2 circuit by means of the C contacts and is "held up."

The circuit of W1 is always closed either through the A or the B contacts of some contactor. When passing through the A contacts of a shut contactor it simply passes on to the next. When passing through the B contacts it is "picking up" the contactor for it goes through the coil M in passing on to the next contactor.

The circuit of W2 is always closed either through the C or D contacts. When passing through the D contacts of an open contactor the current passes on to the next contactor. When passing through the C contacts of a closed contactor it is "holding up" the contactor for it passes through the magnet coil M.

If there were no relay R all the contactors would close practically at once. When a contactor shuts like S there is a sudden increase of the current to the motors and the contact E is pulled open by the relay R. The circuit of W1 is interrupted and hence contactor O does not close.

When the motor speeds up the current is reduced and E closes when O closes at once, for the current flows again in W1 and the magnet is energized.

So W1 picks up the contactors in succession as allowed to do so by the contacts E; and W2 holds up the contactors when closed by W1 and passes through the contactors, which are open, without affecting them.

The contactors are operated from a controller with four notches forward and two backward. There is no reverse lever.

The controller handle will stay at the off position, but at no other unless held there, as a spring acts against the engineer whether handle is moved forward or backward.

This is a safety device which cuts off the power if the engineer becomes disabled or careless. There is a button on the handle which when the handle is in the off position is idle, but to start the train in order to get power to the motors it must be pushed down and kept down as the handle is moved around.

When the handle is returned to the off position in making an ordinary stop this button is released but does nothing except cut off power from the controller, which has already cut power off from the motors.

Should this button be allowed to rise when handle is in any *on* notch the emergency brake will be set.

The notches of the controller are named:

FORWARD.

1. Switching.
2. Series.
3. Lap.
4. Parallel.

REVERSE.

1. Switching.
2. Series.

When the controller is moved to N. 1 Forward the reverser is thrown to the forward running position, and contactors are closed placing the motors in series with all resistance in.

This gives a slow speed for moving about the yards, switching and the like. It is also your first speed in starting a train. This speed must not be used very long at one time as the resistances will heat. The proper management of the train is to put on the switching speed and then coast; or if that won't take you then throw to the second notch, shut off and coast.

Notch 2: Five contactors are now automatically energized in succession, separated by a sufficient time to allow the train to accelerate at 1¼ M. P. H. P. S. This time interval between the contactor closings is regulated by the throttle relay.

When these operations are finished the motors are in full series without resistance.

In moving from N 2 to N 3 there is a *bridge* connection thrown across and the contactors put all the resistance in with the two motors in parallel.

Notch 3 is a temporary notch and the handle is at once moved to N 4 when the resistances are automatically cut out at such intervals as will accelerate the train at 1¼ M. P. H. P. S.

This finally places the motors in parallel without resistance.

If the engineer wishes the handle can be thrown *at once* to N 4 and the train will move forward at 1¼ miles acceleration. The contactors make all the above mentioned changes automatically, so that 40 seconds after the start the train is moving at the rate of 50 M. P. H.

In fact to get the quickest and smoothest start this is the best way to handle the controller.

LESSON 37.

SINGLE-PHASE COMPENSATED MOTOR EQUIPMENT.

WITH SERIES PARALLEL CONTROL.

Electric railway motors in general use throughout the world are operated, as is well known, by direct current with a trolley voltage of about 600 volts. For heavy service and extended systems the cost of copper required at 600 volts becomes a serious item, and for some time there has been felt the need of a higher trolley voltage. The use of alternating current for the trolley would admit of a higher voltage than is possible with direct current, as the voltage could be reduced by a transformer on the car to the potential required by the motors. The development of large power stations and transmission systems has been principally with alternating current, requiring rotary converters, or other commutating devices for changing the alternating current into direct current suitable for the operation of electric railways. Obviously there would be a great advantage in a railway motor equipment that could be operated from an alternating current high voltage trolley and without the necessity of intermediate commutating devices. Such an alternating current equipment would offer a further advantage if it could be operated both on alternating extensions of existing systems and also on the direct current trolley where the latter is already installed.

For several years engineers have been working on this problem, and have developed a type of alternating current equipment suitable for general traction work.

The activity displayed in Europe in adapting the three-phase alternating current motor to the conditions of railway service has never been fully shared by American engineers, due to the limitations of the multiphase* induction motor. The development of the single-phase compensated motor (with a commutator) with its inherent fitness for traction work has attracted very wide attention among railway interests, and work of a practical nature has been actively pushed on both sides of the Atlantic. Considerable importance is therefore attached to the operation in regular service of single-phase alternating current motors. Its commercial possibilities are largely due to the fact that the motors operate with alternating current power outside the city limits and with direct current power inside the city limits.

Alternating Current Motor.

The alternating current motor, Fig. 385 and Fig. 386, is of the "compensated" type, so named on account of the character of the field winding, which fully neutralizes or compensates for the armature reaction. Both the compensated motors and control are adapted for operation on the 2,000 volt alternating current trolley between cities and the standard 600 volt direct current trolley in cities. This ability of the compensated motor equipments to run over tracks equipped with either alternating current or

*Another word for polyphase.

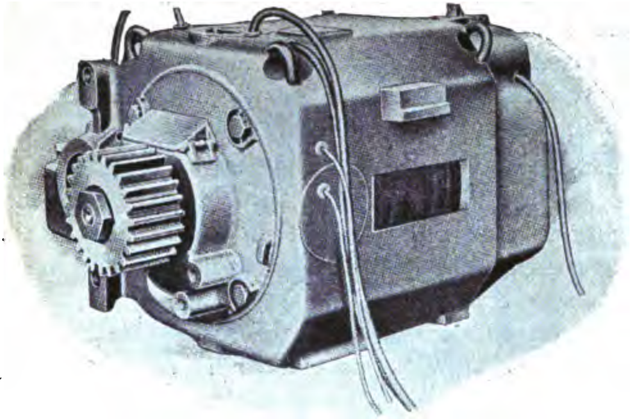


Fig. 385. 75 H. P. Series Compensated Motor. Pinion End.

Fig. 386. Car Axle Side of Motor in Fig. 385.

direct current trolley makes their field of application very broad, as the cars can secure all the benefit of running over existing city tracks without in any way sacrificing their running qualities upon suburban sections equipped with alternating current trolley.

The alternating current motor, with its inherent advantages of high voltage distribution, is eminently adapted to replace the steam locomotive on either high speed passenger or heavy freight haulage work; and as the compensated type of motor is perfectly adapted to operate on both alternating current and direct current trolley, the alternating current motors must be considered a large factor in future suburban railway systems. The compensated motor is essentially a variable speed motor, differing in this respect from the multiphase induction motor, whose constant speed characteristics proved so serious a handicap to its successful adoption in railway work. The characteristics of the compensated motor are very similar to that of the direct current series motor, while its commutating qualities and method of control prove equally satisfactory.

The truck with two 75 H. P. motors is shown in Fig. 387.

The A. C. compensated motor consists of an annular laminated iron field with a winding similar to that of an induction motor, and an armature provided with a commutator similar in general mechanical construction to a direct current railway motor armature. These motors are wound for 200 volts, are permanently connected two in series, and are fed from the 400 volt secondary of an 80 k. w. air-blast step-down transformer carried on the car. The distributed character of the field winding

fully compensates for the armature reaction, so that power factors are relatively high throughout the range of operation. This type of motor is so designed that

Fig. 387. Truck with 150 H. P. of Compensated Motors.

at the free running speed of the car, which is the condition most frequently met with in suburban work, the power factor and efficiency are nearly at their maximum

values. A high power factor is desirable, as it reduces the capacity and cost of the generating and distributing systems, and more especially effects a material improvement in the regulation of the alternating current generators. Unlike a direct current system which has a practically constant potential at the sub-station bus-bars, irrespective of the load, the drop in an alternating current railway system increases with the load. It is desirable therefore to maintain as good a power factor as is consistent with good motor design, in order to limit the total drop of the system to a reasonable amount.

The characteristics for alternating current running are equal to direct current running in meeting the requirements of railway work. Unlike the multi-phase induction motor with its practically constant speed characteristic, the compensated alternating current motor varies its speed with the load, and is thus better adapted to operate trains over an irregular profile. The commutation of the compensated motor is equally satisfactory when running on alternating current or direct current, and this good commutation is secured by careful electrical and mechanical design without resorting to high resistance leads or other expedients liable to give trouble in case of sustained heavy overloads.

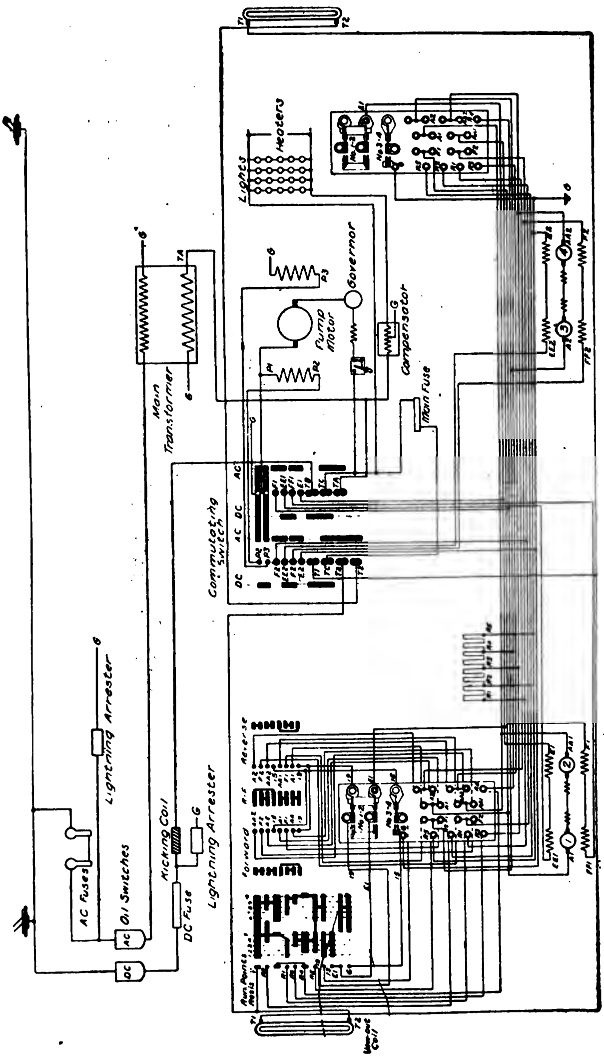
Alternating Current Equipment Adapted for Direct Current.

Our city railway systems have so expanded and cover such a large territory as to make it very objectionable, both on the score of first cost and complication, to install a separate alternating current trolley at reduced po-

tential in order that cars equipped with alternating current motors may benefit from running over city streets at terminals and en route. There is a comparatively small additional expense required to adapt alternating current equipments to run on either alternating current

Fig. 388. Commutating Switch.

or direct current. This is accomplished with the use of a standard K direct current series parallel controller used in connection with a commutating switch, Fig. 388, to change field connections, cut out step-down transformer, change line fuses, etc. The time required to operate the commutating switch is but a few seconds. The scheme of connections for the complete car wiring is shown in Fig. 389.



CAR WIRING FOR ALTERNATING AND DIRECT CURRENT OPERATION

Fig. 389.

The commutating switch is interlocked with two main oil switches, Fig. 390, one being in the high tension alternating current and the other being in the direct current circuit; this interlocking being so arranged that only one switch can be closed at a time, and the commutating switch can only be thrown when the oil switches are in the off position. Owing to the fact that the alternating current trolley construction is off center, while the standard city and suburban trolleys are directly overhead, it has been necessary to provide double

Fig. 390. Oil Switch. Interlocked with Commutating Switch.

sets of trolleys, one for alternating current and the other for direct current, hence the necessity for interlocking the oil switches and commutating switch to prevent trouble should both trolley poles accidentally be up at the same time. Where center wire construction is used on both the city and suburban sections, the alternating current and direct current trolley wires may be overlapped for a short distance to facilitate changing from one trolley to the other.

Sub-Station.

Owing to the fact that 25 cycle, three-phase generators are almost universally used to supply rotary converters in existing interurban railway systems, both the design of the compensated motor and the alternating current distributing system is adapted to operate from existing 25 cycle generating stations. As the alternating current motor is single-phase, a single-phase generating and distributing system commends itself on account of its simplicity. The step-down transformers may be tied together on the low tension side through the trolley with consequent reduction in amount of copper required. Each sub-station acts as a reserve to the adjacent one, and a transformer may be cut out without shutting down a trolley section.

Trolley.

The form of alternating current trolley used is well adapted to the requirements of steam roads where the local service is taken care of electrically and through passenger traffic and freight handled by steam locomotives, pending a complete change to electrical operation. The trolley wire and insulators being off center of track are not exposed to the gases of the locomotive exhaust with consequent deterioration, and furthermore a catenary* construction placed off center can be hung much lower than a standard center wire without interfering with brakemen on freight cars. A low running trolley at the side of the car is also preferable in main line

*See Lesson 83.

operation, as it conforms better to the clearance diagram of such roads without calling for too great a change in height of the trolley wheel or bow.

Control.

With equipments operating with both alternating current and direct current power, it is preferable to utilize the standard series-parallel controller in order to minimize the weight of controlling apparatus. Such a method of operation will not give quite so high efficiency when accelerating with alternating current as could be obtained with potential control. This difference in efficiency, however, is very small, partly due to the infrequency of stops occurring upon those sections of the road equipped with alternating current trolley, but principally due to the flexible character of the alternating current motor which gives a high efficiency of acceleration with series-parallel control.

With modern suburban cars, especially those equipped with train control, air brakes, air compressors, etc., there is some difficulty in suitably locating the power apparatus, even when equipped for direct current running only. With cars equipped for both alternating current and direct current running, using series-parallel controller, there will be required but slightly more space and weight than for direct current running only. Should, however, advantage be taken of the slightly better efficiency of alternating current potential control, such cars must be operated by alternating current upon suburban and city sections with the resulting disadvantages, or the installation of two separate controlling systems must be consid-

ered, necessitating a considerable increase in weight and difficulty in providing room for the necessary apparatus.

The efficiency of the potential control is not over 2 or 3 per cent higher than that of the series-parallel control, but the use of the latter, permitting operation with both alternating current and direct current, secured the advantage of the higher efficiency of the motors when running with direct current over city streets.

Fig. 391. Air Cooled Step-Down Transformed.

For locomotive or other service where no necessity exists for operation over city direct current systems, the potential method of control does offer advantages sufficiently great to warrant its adoption.

The 80 k.w. step-down transformer, Fig. 391, is air cooled, forced draught being obtained by the motion of the car itself. The transformer is suspended below the

car floor, and all primary leading-in wires are carried in brass tubing which is grounded. Car lighting and heating are effected from the direct current trolley in the standard manner, and from the alternating current trolley from the secondary of the transformer. Trolley poles and wheels are of standard design, the alternating

Fig. 392. Air Compressor with Compensated Motor.

current trolley pole being somewhat shorter, as this wire is lower than the direct current trolley. The base of the alternating current trolley is treated with vacuum compound, and further insulated from the car body by composition insulators. The air compressor for the brakes and whistle is operated by a compensated motor which operates from both alternating current and direct current circuits. Fig. 392.

Comparative Operation on Alternating and Direct Current.

It is instructive to compare the performance of the compensated motor equipment when operated with alternating current and direct current.

Comparative Alternating Current and Direct Current Runs.

	D. C.	A. C.
Length of run	1.6 miles	1.6 miles
Weight of car	31.55 tons	31.55 tons
Time	180 seconds	180 seconds
Average current on	229 amperes	346 amperes
Average voltage	606	425
*Kilo-volt-amperes full speed on level	98	110
Volt-ampere-hours per ton-mile of given run	86.3	125.5
Average speed	32 m. p. h.	32 m. p. h.
Schedule speed including 15-second stops	29.5	29.5

The lower volt-ampere-hours per ton-mile of the direct current run are partly due to the better efficiency and power factor of the compensated motor when run with direct current, and partly due to the somewhat higher rate of acceleration, permitting some coasting and resulting in a more efficient speed-time curve. The difference in kilo-volt-amperes alternating current and direct current depends upon the length of the run, and

*Another name for kilowatts.

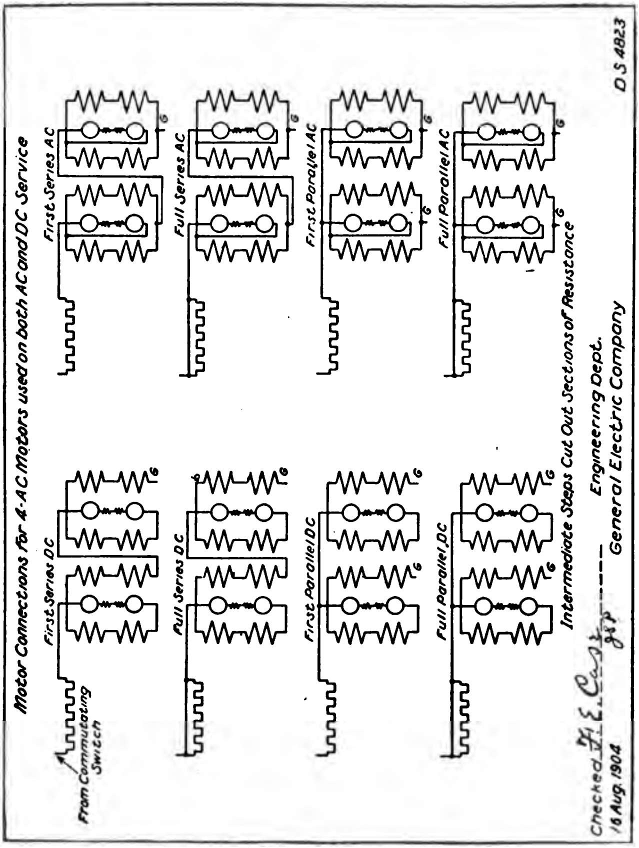


Fig. 393. Arrangement of Fields and Armatures when Running D. C. and A. C.

the values approach each other more nearly the longer the run. It will be noted that the compensated motors run the car at practically the same speed with 200 volts per motor alternating current and 300 volts direct current. This uniform speed is obtained by series paralleling the fields as shown in diagram of connections. Fig. 393.

Commercial Possibilities.

The compensated motor, having demonstrated its fitness for traction work, opens up possibilities in converting main line steam roads which were closed to the direct current motor and the rotary converter combination on the score of first cost of operation. The form of trolley suspension used is capable of being operated at more than 2,000 volts, which together with its mechanical construction, helps to solve the question of current collection of heavy units at high speeds. The commercial development of the alternating current motor is opportune, as steam railway managements throughout the country are displaying great activity in acquiring competing electric roads and in electrically equipping portions of their systems now operating at a loss with steam locomotives. The compensated motor is well qualified to meet the conditions of local passenger service, and holds out the promise of much larger possibilities in the way of direct competition with the steam locomotive in main line work.

Fig. 394 shows car equipped with above described apparatus.

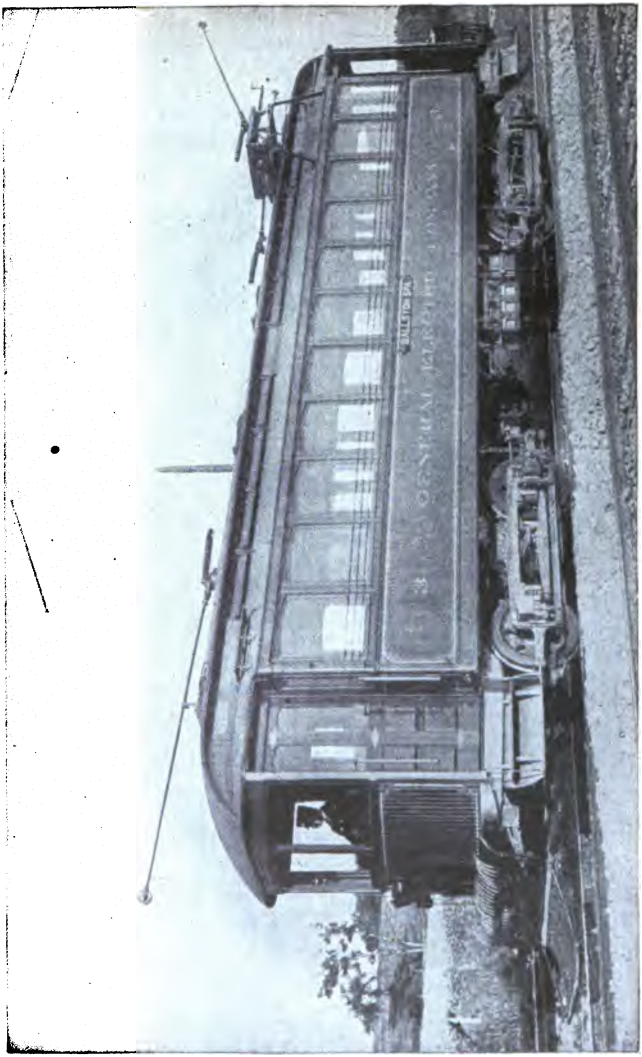
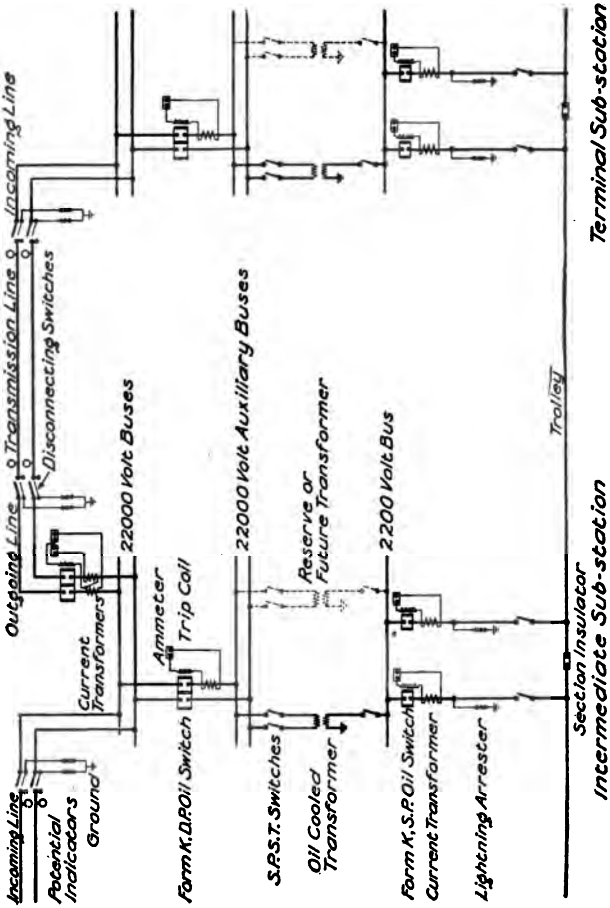


Fig. 394. Car Equipped with Compensated Motors for Operation on A. C. or D. C.



DISTRIBUTION SYSTEM FOR SINGLE-PHASE RAILWAY, SINGLE-PHASE TRANSMISSION

Fig. 395.

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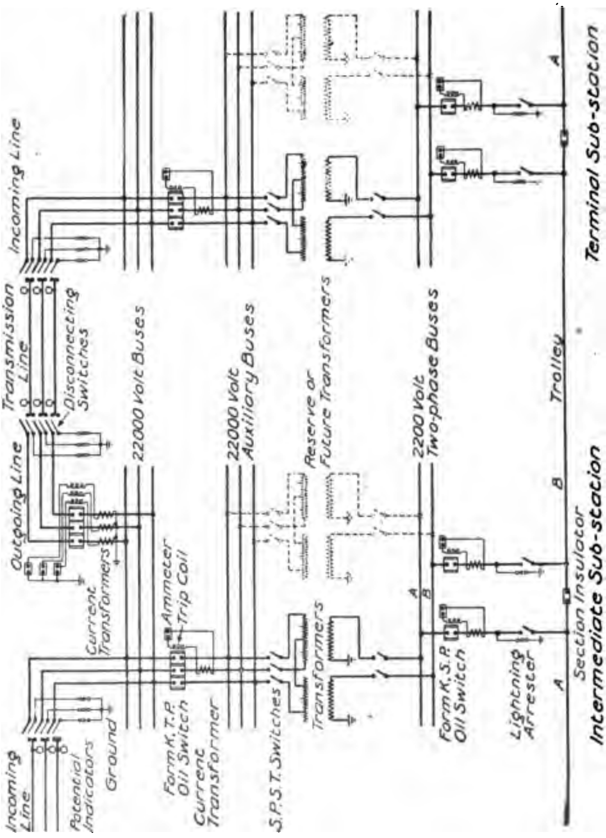

Fig. 396.

DISTRIBUTION SYSTEM FOR SINGLE-PHASE RAILWAY. THREE-PHASE TRANSMISSION. SINGLE TRACK

The connections between the transmission line and the trolley wire are shown in Fig. 395, where single-phase current is used throughout. With a three-phase transmission line, Fig. 396 shows the connections.

LESSON 38.

SPRAGUE-GENERAL ELECTRIC MULTIPLE UNIT CONTROL FOR ALTERNATING AND DIRECT CURRENT OPERATION.

Since the first single-phase equipment was placed in commercial operation, the advantages gained by the adoption of such a system for certain phases of railway work have become more generally recognized. In consequence its field has enlarged, and now there is a demand for such cars equipped with multiple-unit control. The General Electric Company has designed and developed suitable apparatus capable of controlling both single cars and trains equipped with single-phase motors when operating on lines supplied wholly with alternating current, or with alternating current on one portion of the line and direct current on another.

In general the alternating direct current multiple-unit system of control is similar to the well-known Sprague-General Electric type M control for direct current operation. The changes necessary in the type M control to adapt this apparatus for alternating current operation, are of a simple nature, and in this later development all the essential features and advantages of the older type of construction are maintained.

The multiple-unit system may conveniently be divided into two parts, the first consisting of a motor controller, composed of a number of electrically operated switches

called "contactors," which take the place of the ordinary cylinder controller, and may be considered as a more refined development of such, designed to handle currents of too large a magnitude to be dealt with by the ordinary controller. This apparatus is usually installed underneath the car.

The second part comprises a "master controller," the function of which is to operate the contactors; and a multiple cable, which extends the length of the train, and is provided with couplers between cars.

The train line apparatus, such as connection boxes, couplers, cut-out switches and cables, are identical with those used on standard type M equipments for direct current operation.

To adapt such a system for both alternating and direct current operation changes are made in the circuits of the contactor coils when the car passes from an alternating to a direct current section, and vice versa; the motor fields are also connected in series for direct current operation, and in parallel for alternating current. These changes are made as the car passes the short dead section separating the alternating and direct current portion of the trolley line, and at the same time either the resistance or compensator leads are put in circuit, as required.

For alternating current operation "Potential Control" is used; that is, acceleration is obtained by increasing the potential at the motor terminals by connecting compensator taps of successively increasing voltage to the motors in proper sequence, corresponding to the resistance steps of the direct-current equipment.

When the cars are to run on both alternating and

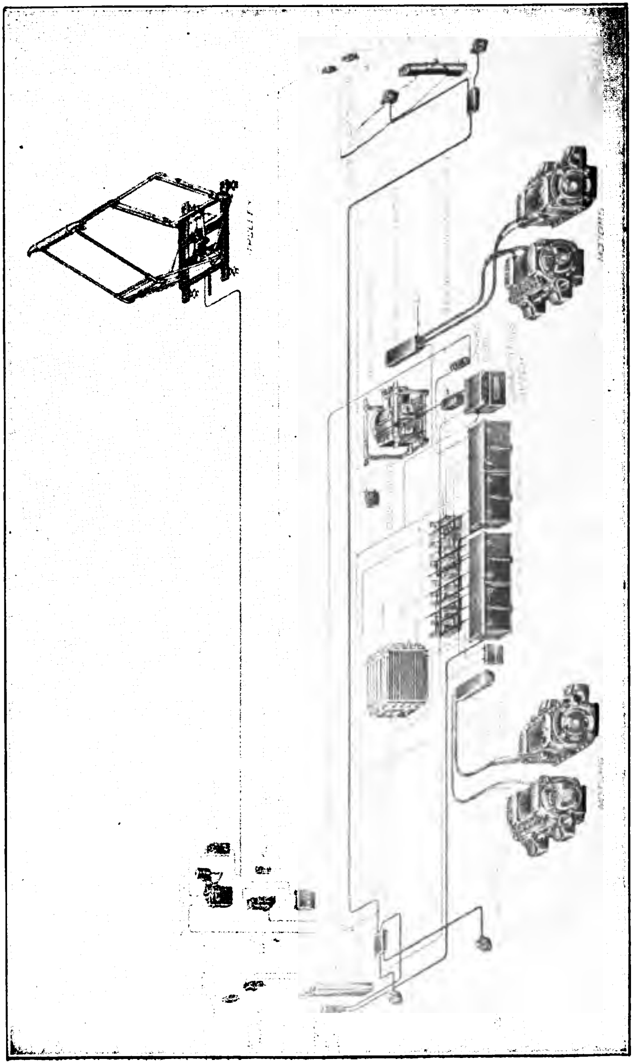

Fig. 397. Arrangement of Sprague-General Electric A. C. and D. C. Control on Car.

direct current lines, a special switch is supplied to make all the necessary changes in the circuits, and suitable cast grid rheostats are provided for giving the desired direct current acceleration which is obtained by cutting out resistance from the motor circuit step by step, in an exactly similar manner to that employed on ordinary direct current equipments.

Fig. 398. Direct Current Contactor.

List of Apparatus.

The apparatus for each alternating-direct current car equipment consists essentially of:

Master controllers, Fig. 378.
Train cable and couplers, Fig. 397.
Contactors, Figs. 398 and 399.

Compensator, Fig. 400.
Set of rheostats.
Commutating switch, Fig. 388.
Trolleys, Fig. 397.
Motor cut-out switches, and
The necessary protecting devices.

The master controller and contactors are same as type M equipment.

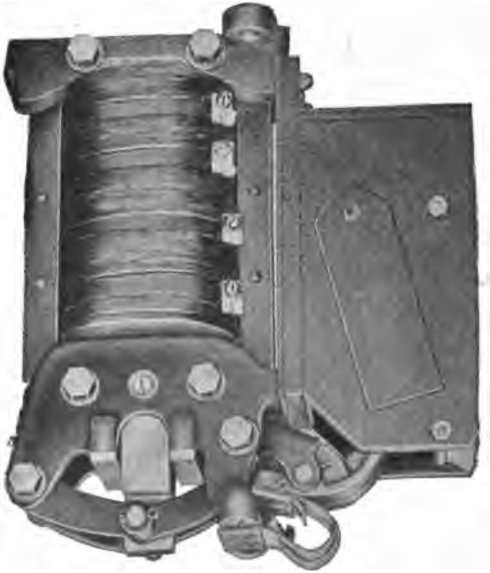

Fig. 399. Alternating Current Contactor.

Compensator.

The compensator, Fig. 400, which reduces the trolley potential to the proper voltage required for the motor, is of the oil-cooled type, suitably designed for suspend-

ing underneath the car body. It consists of a specially designed transformer structure entirely enclosed in a corrugated iron casing. The end castings are provided with stuffing boxes to prevent any leakage of oil where the taps enter. The coils of the compensators are specially well insulated to withstand the vibration to which such equipments are subjected. Taps giving various voltages are provided for controlling the speed of the motors.

Fig. 400. Compensator.

Rheostats.

The rheostats are of the standard cast grid type, and are exactly similar in all respects to those used on the ordinary street car equipment.

Commutating Switch.

The commutating switch, Fig. 388, is used to make all the necessary changes in the circuits when the car passes from an alternating to a direct current section of the line, or vice versa. All such changes are accomplished by one operation.

Fig. 401. Oil Switch for A. C. with Low Voltage Release.

Current Collectors.

The current may be collected by means of standard trolley wheels, poles and bases applicable for high speeds, or, when desired a sliding or rolling contact collector of the pantograph or bow type, such as has been used in Germany for a number of years, may be employed.

Insulation from the roof of the car is obtained by specially treated hard wood planking mounted on high tension insulators.

Protective Devices.

The oil switch, Fig. 401, in the high tension circuit is electrically operated and held closed by a coil energized from a small auxiliary transformer. This switch is protected by an expulsion fuse, Fig. 402. The main direct current switch, Fig. 403, has the same characteristics

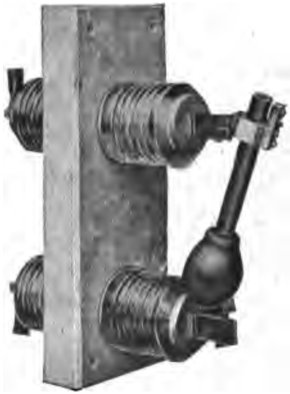

Fig. 402. Expulsion Fuse Rated at 30 Amperes with 6,600 Volts A. C.

as the oil switch but is energized directly from trolley. It is insulated for the alternating current line voltage and is protected by a copper ribbon fuse with magnetic blow-out. Fig. 404.

A single fuse of the magnetic blow-out copper ribbon type is used for protecting the motor circuit when operating either A. C. or D. C.

Both the alternating and direct current circuits are protected by suitable lightning arresters.

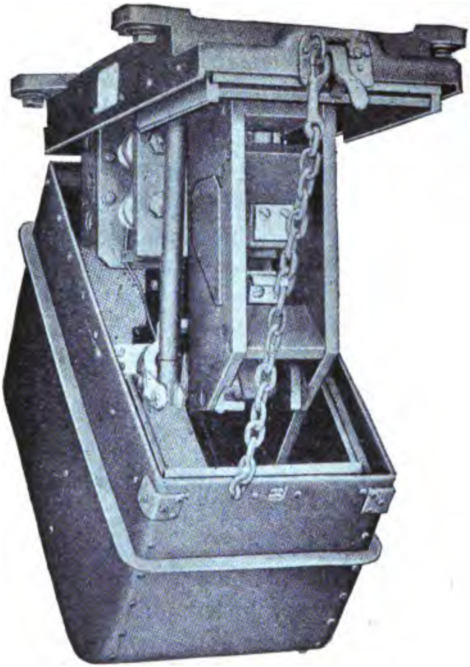

Fig. 403. Direct Current Switch.

Fig. 404. Fuse Box for D. C. Circuits.

Cut-Out Switches.

A cut-out switch is used in connection with each pair of motors to disconnect a disabled motor when any car is operating individually as a single unit. As all the leads from each pair of motors run through their own cut-out switch, this is accomplished by simply turning the handle of the switch to the proper position.

Train Line.

The train line consists of a cable composed of ten conductors and runs through the entire train; the connections being made between the individual cars by means of suitable couplers. The master controller is connected to the train line at the connection boxes on each car, from which a multiple cable is run through the control cut-out switch to the operating coils of the contactors.

Auxiliary Circuits.

The circuits for the air compressor motor and those governing the lighting and heating of the car, are all protected by enclosed switches and fuses.

Air Compressor Motor.

The air compressor motor of the alternating-direct current compensated type; its exciting fields are connected in parallel for alternating current and in series for direct current operation. Fig. 392. The necessary

changes in connection are made through the medium of the commutating switch already described. The air pressure is regulated by a standard General Electric air compressor governor. Fig. 476.

Motor Connections.

The arrangement of the motor connections are dependent upon the service conditions required. The usual arrangement for both alternating and direct current operation is with all the motors on the car connected in series which permits of the use of fewer pieces of controlling apparatus and of less current carrying capacity than would be necessary if the motors were connected in parallel.

Method of Control.

During alternating current operation the car is controlled as follows:

On the first point of the master controller the motors are connected to a compensator tap giving approximately half voltage. After this point acceleration is obtained by cutting in more sections of the compensator winding, until on the last tap the motors are connected to the full working voltage tap. A small section of cast grid rheostat is cut into circuit during the instant of changing the motor connection from each compensator tap to the succeeding tap. This permits of an uninterrupted current supply to the motors without short-circuiting the various sections of the compensator winding. There are five steps on the master controller for alternating current operation, each constituting a running point, and seven

steps for direct current operation, the last step being the running one.

Changing from Alternating to Direct Current Operation.

The change from alternating to direct current operation is accomplished at a dead section in the trolley wire. At the instant the car enters this dead section whichever main switch is closed will open owing to the fact that the circuit energizing its retaining coil is broken. The car can run over this dead section at full speed and all that the motorman has to do to obtain the proper connections is to throw the commutating switch and close the main alternating or direct current switch, as the case may be.

LESSON 39.

WESTINGHOUSE UNIT SWITCH SYSTEM.

This system is operated by a small controller (Fig. 405) which has a center or off position and three positions on each side of the center for forward and reverse movements.

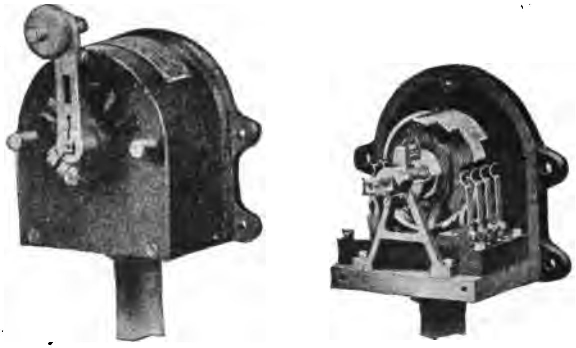

Fig. 405. Controller. Cover on and off.

The circuits which this controller opens and closes are supplied with current by a 14 volt storage battery, there being a duplicate set on each car.

The arrangement of motor circuits is done by a set of 13 switches or contactors which are opened and closed by small pneumatic cylinders drawing their supply through electro-magnetically operated valves, from a reservoir containing 70 lbs. pressure.

These electro-magnetic valves are operated by the circuits which are open and closed by the controller.

These 13 switches, with their air cylinders, magnetic valves and air reservoir, together with a blow out magnet to suppress arcing at switches, are all arranged into a

Switch Group.

This switch group is shown as it appears when bolted to the under frames of car in Fig. 406. With covers

Fig. 406. Switch Group. Cover on.

removed it looks as in Fig. 407. The cast iron flange which is bolted to car frame shows plainly. Below are the magnetic valves, and at bottom are the arc chutes of the switches.

The sectional view in Fig. 408 shows the different parts of the switch group.

Air is supplied from the reservoir N by action of the electro-magnet L through a valve not shown by means

of a passage as on right side of figure (where the section comes between two cylinders) to the cylinder above the piston C.

The piston is forced down against the spring P, which will return piston to original position when air is exhausted.

Fig. 407. Switch Group Opened.

This swings the outer end of arm E up against terminal H. The two studs M are the terminals of a motor circuit. They are insulated from the plate J which they are in. T also serves as the pole piece of the large magnet A which is the blow out for all switches.

The end of E has a rocker motion controlled by spring F, so that a rubbing contact is made with H. The extreme end of the contact piece D is a removable piece G.

The upper end of the piston rod engages some contacts at K. These interlocks control the passage of current to next valve magnet and thus produce an automatic acceleration.

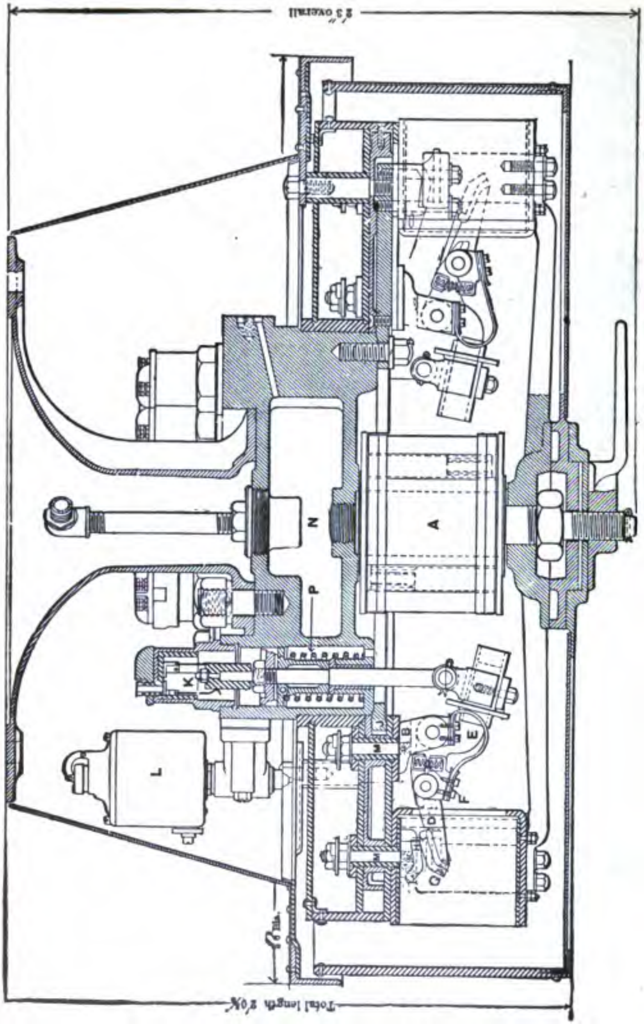

Fig. 408. Sectional View Switch Group.

Since the normal position of all switches is open, any failure of air supply will allow all switches to open and no harm will result.

Controller.

In the off position of the controller all unit switches are open and the reverser in position last used. The first position of controller throws the reverser (by operating its air valve) to forward or reverse position, according to whether handle is moved to right or left of center position. If reverser is already in correct position it simply stays there. In addition the motors are placed in series with all resistance in.

The second position puts the "lift up" and "retaining" wires in commission and by means of interlocks and the limit switch* (explained in Lesson 36) in four steps it cuts out resistance and places motors in full series.

The third position changes motors to parallel with resistance and then cuts out resistance until full parallel is reached.

Limit Switch.

This switch (Fig. 409) consists of a copper disk resting on two terminals which are in the pick up wire. The magnet which by means of an iron core raises the disk is in series with one of the motors. At any time the current input exceeds the proper amount the limit switch is operated and pick up wire opened, thus arresting further closing of unit switches. (See Lesson 36.)

*This device is practically a *relay,* but is called a *limit switch* by Westinghouse Co. and a *current limit or throttle relay* by General Electric Co. In Lesson 36, it is simply called a *relay.*

Reverse Switch.

This switch (Fig. 410) with its magnetic valves and air cylinders arranges the motor field and armature cir-

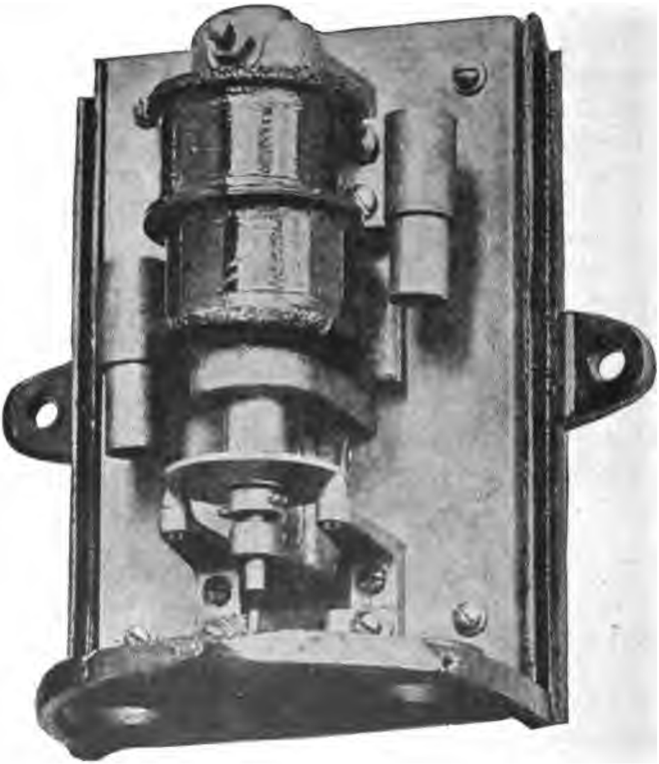

Fig. 409. Limit Switch.

cuits for forward or reverse running. It is provided with an interlock so that switch group is inoperative

unless the reverse switch is fully thrown, and making good contact, in the direction indicated by controller handle.

Storage Battery.

The current for magnet valves is furnished by two storage batteries of 7 cells each, with 40 ampere hours capacity. One battery is on operating circuits, while the other is being charged by the lighting circuit.

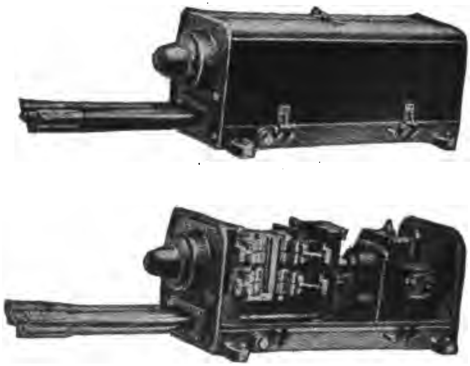

Fig. 410. Reverse Switch.

The positive side of the battery is connected to train cable through controller and the negative side to the valve magnets. In this way when a train cable circuit is completed at the controller current flows through valve magnet.

Circuit Breakers.

Each car has a circuit breaker which is reset after blowing by a magnet. All the breakers of a train can be reset at once by using the reset switch on the car the motorman is on. In a similar way in case of electrical troubles all the circuit breakers may be opened or tripped by a switch in motorman's compartment. Current may be cut off from any one car by opening line switch cut out without affecting operation of other cars.

Line Relay.

A device similar to limit switch, which is connected as a shunt across supply mains. It has a series resistance to protect it from the high voltage. Its copper disk is held against the terminals by the magnet against the tension of a spring. Should the voltage fail on trolley or third rail, this spring will open the circuit from the storage battery, the unit switches will open and no harm will result when voltage is suddenly re-established.

Operation of System.

Fig. 411 gives a wiring diagram of the unit switch control, the operation of which will be better understood after a study of Fig. 412.*

*In studying this and other diagrams, if a few pieces of paper be cut of such a size as to just cover the numbers of the switches or contactors, and as the text says the switches close, cover the numbers, the circuits formed will be closely indicated.

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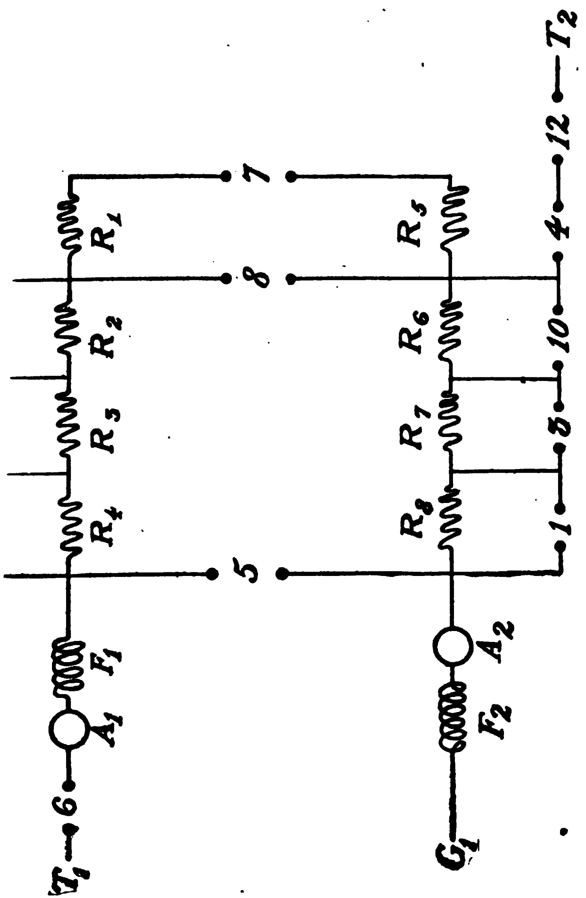

Fig. 412. Diagram of Motor Control. Unit Switch System.

With controller on second point the following things happen: Switch 8 is closed, cutting out resistances R1 and R5;* the interlock† on 8 closes switches 9 and 10. Looking at Fig. 411, where the interlocks are shown directly above the air cylinders of the switches, you will see that when 9 closes its interlock closes and when 10 closes its interlock opens.

It is the closing of interlock on 9 which closes switches 11 and 3, cutting out more resistance. Switch 3 has no interlock, but the interlock on switch 11 closes switches 1 and 2, thus placing motors in full series.

With controller on third point all these switches remain closed and 5 also closes. This does not produce any electrical change, but through its four contact interlock it opens switches 7, 8, 9-10,‡ 11-3, 1-2. It does this to prepare circuits for next change; and it keeps the motors in series itself by cutting out all resistance.

Now that switch 10 is open its interlock is closed again (Fig. 411) and current flows from the low contact on interlock 5 to the magnet coil 4-1, which closes switches 4-12-13.§

The state of affairs is now such that if switch 5 were

---

*Because current will flow around the low resistance shunt instead of through resistance grid.

†Interlocks move down when switches close.

‡These switches are mentioned together in this way, because they always open or close together, being controlled by the same magnet valve. See Fig. 411.

§Because when switch 4 closes its interlock energizes lower coil which is marked 4-12-13. This coil closes switches 12 and 13, and keeps switch 4 closed, even though later switch 10 will close and open its interlock.

to open, the motors would be in parallel with all resistance in.

When controller is on first point switch 6 is closed, its interlock closes switch 7. The motors are then in series with resistance.

The interlock on 4 has right hand finger short enough so that when switch is closed coil 5 is cut off of circuit and switch 5 opens thus, placing motors in parallel with resistance. Although 12-13 close a fraction of a second before 5 opens no harm could result, for the state of affairs is as follows:

There is a circuit from T_1 to G_1 containing two motors in series; perfectly safe. A circuit from T_2 to G_2 containing resistance R_2, R_3, R_4, R_6, R_7 and R_8 amounting to 1.36 ohms; sufficient to prevent a short circuit. A circuit between T_1 and T_2 containing a motor and the resistance R_8, R_7 and R_6 also perfectly safe.

The interlock on 4 when closed energizes the short left hand contact which closes switches 9-10. Then in succession as described before switches 3-11 and 1-2 close, thus placing motors in full parallel.

Automatic Acceleration.

In the system of automatic acceleration described in Lesson 36 the contactor coil was shifted from pick up to hold up circuit.

In the unit switch system most of the valve magnets of the air cylinders have two operating coils called the pick up and retaining coils. The pick up coils are in circuits affected by the action of limit switch and the retaining coils are in other circuits.

Thus the controller and interlocks may arrange circuits so that a certain switch would close were it not that the circuit is open at the limit switch. As soon as that switch closes the valve magnet operates and switch closes.

If a certain switch is being held by the retaining coil the action of limit switch has no effect on it.

In Fig. 411 the wire L or lifting circuit comes from the limit switch, while wire R or retaining circuit comes directly from battery.

LESSON 40.

LOCOMOTIVE FOR THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD USING EITHER ALTERNATING OR DIRECT CURRENT.*

General System—The New York, New Haven & Hartford Railroad Company has started the electrical operation of their main line between New York City and Stamford, Conn., a distance of over 33 miles. That portion of the road which lies between the Grand Central Depot and Woodlawn, New York, utilizes the tracks of the New York Central Railroad and constitutes a portion of the electrical zone of that company within which the direct-current third-rail system is installed. Between Woodlawn and Stamford the road is equipped with the Westinghouse single-phase alternating-current system and the trains will be operated by electric locomotives which take alternating current from the overhead trolley line. The power station of the New Haven Company is located at Riverside, Conn., three miles from Stamford. The power equipment includes three Westinghouse-Parsons horizontal steam turbines driving 25 cycle, alternating-current generators of the revolving field type, which have a rated continuous capacity of 3,750 kw. each when running single-phase and of 5,500 kw. when supplying a three-phase service. The generator armatures are designed for

*To Railroad Men (a monthly magazine) we are indebted for cuts.

both single-phase and three-phase connection. They are wound for 11,000 volts and are connected direct to the trolley system. Absolutely no transforming stations or reducing transformers along the line will be required, but the entire system will be operated direct from a single central station without the interposition of substations or auxiliary apparatus of any kind between the switchboard and the cars. This desirable simplicity is made possible by the alternating-current system and the high trolley e.m.f. which will be employed. It is probable that, with a service equivalent to that now given by steam locomotives, electrical operation can be extended a distance of 20 miles beyond Stamford without the use of a higher transmission potential or the introduction of transforming stations.

High Potential Trolley Line—The overhead construction is supported from steel bridges which will be located every 300 feet and which will normally span from four to six tracks, though on certain portions of the road longer bridges will be employed. Every two miles the bridge is made of a specially heavy construction—forming an anchor-bridge to make the overhead structure even more secure. The trolley wires are hung from steel messenger cables which, in turn, are supported by heavy insulators mounted upon the steel bridges. Each trolley wire is suspended from a pair of steel messenger cables by triangular supports, forming a double catenary suspension of great strength and stiffness. The triangular supports are placed about ten feet apart. The messenger cables will have a total sag of about six feet, while the trolley wire itself will be held in a practically horizontal position.

The trolley system is divided into sections approximately two miles in length, each section being separated from its neighbors by heavy line insulators. Adjoining sections will be connected through automatic oil-type circuit breakers. If a short circuit or other trouble occurs in any section, therefore, it can be cut out without disturbing the operation of other portions of the line. Two feeder wires will be carried the whole length of the alternating-current line and will be so connected to the various sections of the trolley system by automatic switches that any section of four or more trolleys can be cut out of service and those beyond kept in operation.

The trolley wires will be held normally at a height of 22 feet above the track. The overhead system is designed with a safe margin to meet the stresses imposed by the most severe conditions—such as high winds or heavy coatings of ice.

Locomotives—Thirty-five locomotives are to be furnished by the Westinghouse Company, suitable for operation on the direct-current division between the Grand Central Depot and Woodlawn, and on the alternating-current portion of the line between Woodlawn and Stamford. Ten locomotives have already been constructed.

The frame, trucks and cab of the locomotive were built by the Baldwin Locomotive Company, according to designs developed with the co-operation of the New Haven Railroad and the Westinghouse Electric and Manufacturing Companies.

The Frame—As the entire space between the wheels is occupied by the motors, it was impossible to transmit the draw-bar pull through the center line of the locomotive; so the entire strain is carried by the strong plate girders

which make up the locomotive frame. A Westinghouse friction draft gear is mounted directly underneath the box girder at each end and is applied to two steel bumpers laid horizontally between vertical gusset plates on the ends of the side channels.

The Trucks—The running gear consists of two trucks, each mounted on four 62-inch driving wheels. The trucks have side frames of forged steel to which are bolted and riveted pressed steel bolsters which carry the center plates. The weight on the journal boxes is carried by small semi-elliptic springs with auxiliary coiled springs under the ends of the equalizer bars, to assist in restoring equilibrium. A very strong construction is secured without excessive weight by the use of bolsters 30 inches wide at the center plate and extended to nearly double that width at the ends which are bolted to the side frames. Center pins 18 inches in diameter transmit the tractive effort to the frame. They are well lubricated to permit free motion on curves. The truck pedestals are provided with wedge and gib adjustments to take up wear, and the bearing brasses are easily removable by hand. The distance between truck centers is 14 feet, 6 inches.

Cab—The cab is formed of sheet steel mounted on a framework of Z bars which supports the walls and roof. Windows are provided at each end, giving an outlook on both sides and in front of the locomotive; and the driver is so close to the front that he can see the track a very few feet ahead. This advantage is not possessed by any type of steam locomotive now in service. The master-controllers, auto-transformers, instruments, grid resistances, air operating valves, compressors and other auxiliary apparatus are mounted inside the cab upon an angle-iron

framework which is built into the cab and securely anchored to floor and roof. A clear passage-way is left through the center. Trap doors in the floor furnish easy access to the motors for inspection or repair.

Equipment—The equipment of the locomotive includes four gearless motors, controlling apparatus and auxiliaries.

Motors—The motors are of the gearless type, designed for operation on both single-phase alternating and direct current. They are wound for approximately 235 volts on alternating current and 275-300 volts when operated by direct current. They have normal rated outputs of 250 H. P. on the basis of ordinary railway practice, and a continuous capacity of 200 H. P. each. The locomotive therefore, has a continuous operating capacity of 800 H. P.

The motor frames are made of cast steel and are of a circular, skeleton form. They are divided horizontally into two parts in order to give access to the inside of the field or to the armature. A laminated core with slotted projecting poles is built up within this frame and wound with field coils of flat copper strap insulated between turns with asbestos and filled with an insulating compound which is heat-conducting and water-proof, so that a sealed coil is produced which can withstand moisture and internal heat. Copper bars are placed in slots in the pole faces and connected to form a continuous neutralizing winding which forms part of the circuit including the main field coils, the armature coils and the auxiliary winding, all in series. This auxiliary winding produces a magnetic field which opposes and neutralizes the reaction of the armature. It is so formed that it need not be disturbed in order to remove the main field coils.

The armature core is built up of soft steel punchings which are assembled on a cast iron spider and held in place and keyed to prevent their turning. The surface is slotted and the armature winding is arranged in three layers. The two upper layers are composed of copper strap connected to form the usual direct-current type of winding. The third layer constitutes the preventive winding. It is connected between the commutator and the main winding. This preventive winding is so proportioned as to prevent sparking, due to the normal working current and that which is produced in the coil under commutation, when short-circuited by the brush in an alternating field. The individual coils are insulated along their entire length by overlapping layers of mica tape, and each group is further insulated from the core by a molded mica cell. The completed winding is held firmly in position by insulating wedges. The ends are banded down against the coil supports.

Suspension—The weight of each motor is carried on a frame which passes over the wheels and side frames and rests on the journal boxes. Each frame carries four bolts which receive the weight of the motor and each bolt is fitted with a heavy coil spring at its lower end through which all weight is transmitted to it, so that the motor is carried on very flexible springs and is independent of the truck frame. The torque of the motor and the jar caused by sudden starts and stops are transmitted from the motor to the truck through heavy tie-rods which affect the motion of the motor only lengthwise of the locomotive. The armature is not placed directly on a shaft but is built up on a quill through which the car axle passes with about five-eighths inch clearance all around. The

bearings which carry the field frame are mounted on this quill and from a flange at each end of the quill seven round pins project parallel to the shaft into corresponding pockets formed in the hub of the driving wheel. The torque of the motor is transmitted from these pins to the wheel through helical steel springs which are wound with their turns progressively eccentric, and which are contained between two steel bushings, the smaller of which slips over the pin and the larger fits in the pocket in the wheel. These springs are under compression both longitudinally and horizontally so that, at all times, they fill the pockets in the wheel but permit a vertical and a lateral motion. Their longitudinal compression between the quill and the segmental cover over the outer ends of the pockets in the wheel keeps the motor at all times midway between the hubs. The end play of the motor does not come directly on the wheels but is taken by strong coiled springs inside of the driving pins, which press against the covers in the outer ends of the spring pockets in the wheels. Though normally required to transmit only the torque of the motor and to keep the motor axis parallel to the axle, these springs are amply strong to carry the entire weight of the motor. They allow a total vertical movement of about ¾ inch. The torque of the motor is taken by heavy parallel rods which anchor the frame to the truck above and below the axle and permit vertical or side motion of the motor but prevent excessive bumping strains from coming on the driving springs. If these springs are compressed more than ¼ inch by the heavy centrifugal force exerted by the motor when rounding curves, the force is taken up by noses on the motor which fit into corresponding recesses in the cross ties between the side frames of the locomotive.

This suspension has the advantage of removing all dead weight from the axle, of driving through springs, and at the same time of having the motor thoroughly anchored to prevent undue strain on the driving spring. The only parts of the locomotive not spring supported are the driving wheels, axles and journal boxes.

Forced Ventilation—The motors are arranged for ventilation by a forced circulation of air which enters under pressure, is distributed throughout the motor and escapes through the perforated covers. In the floor of the cab there is a natural conduit formed by the side channels of the frame, the floor and side walls of the cab, and a lower plate, through which air is carried to the motors, transformers and resistances. This method of cooling improves the continuous capacity of the apparatus and is, in a large measure, accountable for the high continuous rating of the motors which almost equals that on the one-hour railway basis. The air furnished to the motor may be taken from the inside of the cab and can therefore be kept relatively clean and dry.

Current Collection—On the direct-current part of the line current is taken from the third-rail system by eight collecting shoes, four on each side of the locomotive, arranged in pairs of two each. There are two pairs on each side, one at each end, for the purpose of bridging such gaps as may occur in the third-rail system. The direct-current contact shoes are designed to work on two forms of third rail—one in which the shoe runs under the rail, and the other on top of the rail. To collect alternating current from the high-potential overhead trolley line, the locomotive is equipped with two pantagraph type, bow trolleys, each of which has a capacity sufficient to

carry the total current required by the locomotive under average conditions—two being provided to insure reserve capacity..

The Control System—On direct current the motors are controlled in series parallel as in ordinary railway practice. In alternating current operation no resistance is used in the regular run, but a small resistance, which constitutes a preventive device to diminish the short-circuiting effect when changing from one transformer tap to another, is employed in passing from one working step to the next. There are six alternating-current voltages or running points, corresponding to six taps from the auto-transformers, and there are a small number of midway steps which are used only in passing between working notches. Experience has shown that the number of steps required in alternating-current operation to give a smooth acceleration is considerably lower than in direct-current practice. In consequence, the controller is so arranged that on alternating current about half as many steps are used as on direct current. Tests so far conducted show that the acceleration on both alternating and direct current is very smooth.

There is one feature of the direct-current control which is not generally found at the present time in direct-current equipments, viz., the shunting of the field for higher speeds. In the series position in direct-current operation the motors have an efficient running point. It is usual railway practice to pass from the series to the multiple position without an efficient intermediate running speed. With the New Haven equipments, however, the type of motor used permits shunting of the field without impairment of commutation or operation and higher speeds are

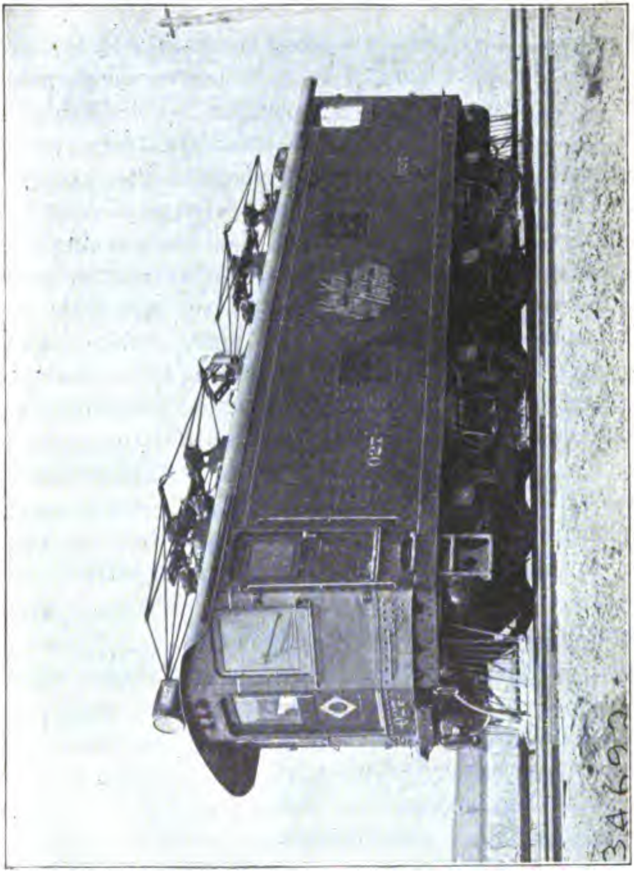

Fig. 413. New Haven Locomotive in D. C. Zone. A. C. Trolleys Down. Third Rail Shoes Down.

provided by shunting the fields before passing into multiple. In this way several efficient running points are obtained between the series and multiple positions; and tests have shown that these motors operate properly on direct current with their fields shunted down to half their normal strength. When operated on direct current, the current is fed directly to the motors. On alternating current, however, auto-transformers are required, as the alternating-current trolley voltage is 11,000. Two such transformers form part of each equipment—one mounted on each side of the cab floor to balance the weight. They are connected in parallel across the high voltage, but on the low-voltage side each transformer feeds one pair of motors through a separate control unit. This means that the control system when operated on alternating current, consists of two normally independent units.

The main controllers are the Westinghouse electro-pneumatic unit switch type. The design differs somewhat from that used in direct-current service, because of the fact that the switches, blow-outs, etc., must operate on both alternating and direct current, as many parts of the controller are common to both systems. The reversing switches are also parts of the unit switch groups. The main controllers are operated from master controllers at each end of the cab. The control system is arranged for multiple unit service, so that two or more locomotives can be coupled to the same train and handled by a single driver.

There are six switch groups, each containing unit switches. The two line switches are so connected in the switch groups that each carries the current supply to each pair of motors when they are operating in parallel com-

Fig. 414. New Haven Locomotive in A. C. Zone. A. C. Trolleys Up. Third Rail Shoes Up.

Fig. 415. New Haven Train.

bination. When the motors are in series, one of the line switches carries the current supply to all. Each line switch is provided with an overhead trip so connected that all of the switches of both switch groups as well as both the line switches open in case of an overload or short circuit on either pair of motors or in the circuit of either pair. The overload trip is automatically locked out when brought into action and cannot be reset until the master controller is returned to the off position.

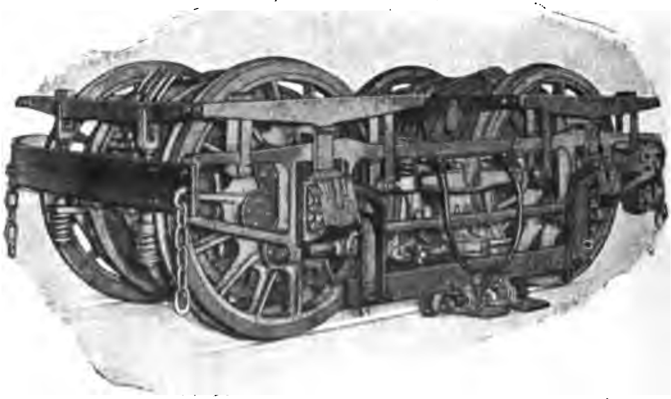

Fig. 416. One Truck of New Haven Locomotive.

The external resistances used in regulating the flow of current to the motors are arranged in two groups which are connected in series when the motors are in series, and in series with each motor when the motors are in parallel. The change over between the direct current third rail and the alternating current overhead system can be made easily and quickly even when the locomotive is running at full speed.

An ammeter is mounted in each end of the locomotive in plain view of the operator when at the master controller.

The master controller is of the drum type and is operated by a lever which moves through an arc of about 60 degrees, with notches and latch wheel to define the dif-

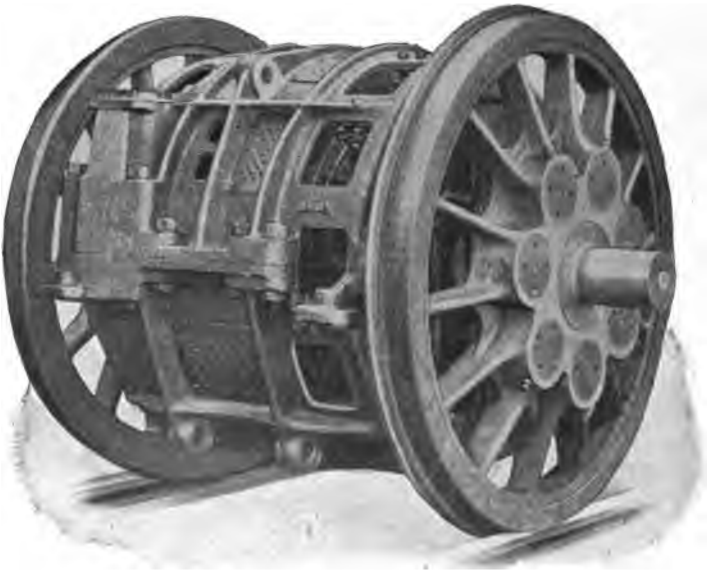

Fig. 417. One Complete Motor for New Haven Locomotive.

ferent positions. Reversing is accomplished by a separate handle which interlocks with the main lever. When the master controller is in the off position, connections are so established that all circuit breaker trips which may be open are closed by the simple closing of a small switch

conveniently located in the locomotive cab. Current is supplied to the control circuits by two sets of 7-cell storage batteries, each of which has a capacity of 40 ampere-hours and weighs 150 pounds.

In connection with the switch groups, cut-out switches are provided so that either pair of motors may be cut out by simply rendering certain switches inoperative. It is thus possible to cut out the motors without manipulating the main circuit.

Fig. 418. Complete Armature Mounted on Locomotive Axle.

Auxiliaries—The auxiliary equipment includes two air compressors driven by motors which can be operated on either alternating or direct current; two blowers driven by similar motors and which furnish air to the transformers, motors and direct-current rheostats; oil circuit-breakers for the high-tension circuits; switches to change the equipment from alternating to direct current; a steam

generator to supply heat to the railway coaches in cold weather; a complete Westinghouse air brake equipment, signal apparatus, automatic bell ringers, whistles, sanding apparatus, etc.

Dimensions and Performance—The New Haven locomotive measures 36 feet, 4 inches over the bumpers and weighs approximately 85 tons. It is capable of handling a 200-ton train in local service on a schedule speed of 26

Fig. 419. Armature Mounted on Quills.

miles an hour, with stops averaging about two miles apart—making in such service, a maximum speed of about 45 miles per hour. It can also handle a 250-ton train on through service with a maximum speed of about 60 miles an hour. With heavier trains it is planned to couple two or more locomotives together and operate them in multiple.

Tests—The tests which have been made on the first locomotive equipped show that it will, without difficulty, meet all the requirements for which it has been designed,

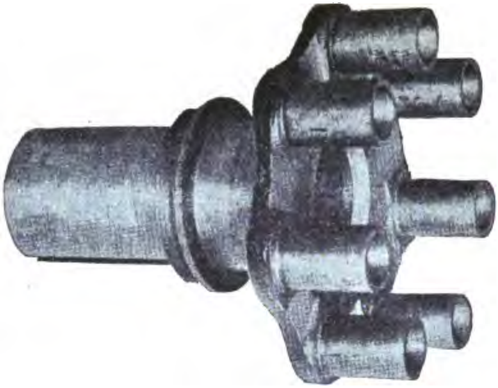

Fig. 420. Driving Quill.

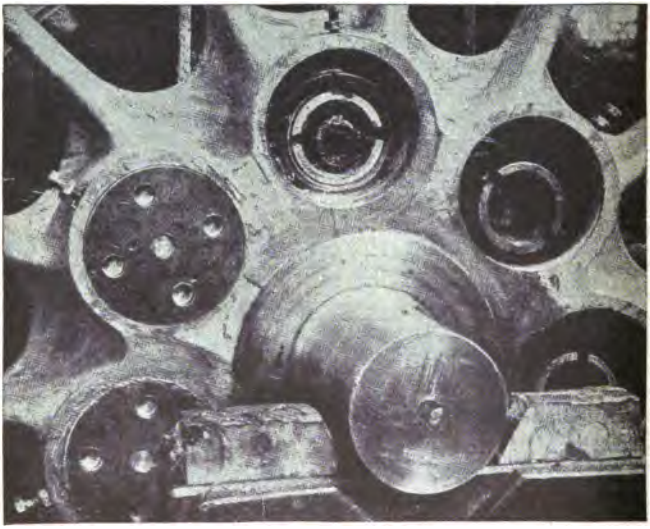

Fig. 421. Pockets in Driver for Fingers of the Quill.

This locomotive has, on actual test, repeatedly accelerated a 200-ton train at a rate of .5 of a mile per hour per second, which is in excess of the rate required by the service conditions of the New Haven road. The locomotive has been operated at speeds above 60 miles per hour without difficulty.

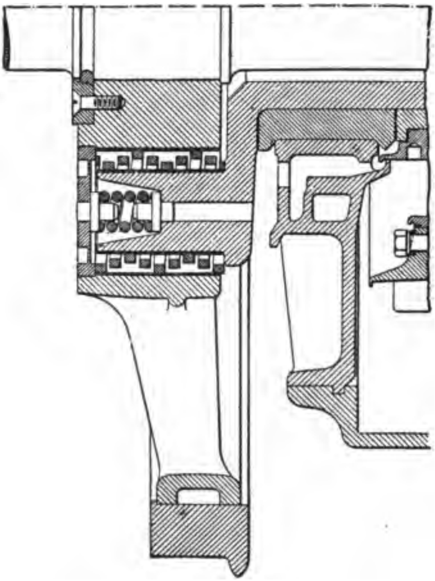

Fig. 422. Method of Placing Springs Between Quill Fingers and Driving Pockets.

In Fig. 413 is shown a locomotive standing in D. C. zone with both trolleys and shoes down; when standing in A. C. zone, as in Fig. 414, both trolleys and shoes are up. In Fig. 415 is shown a regular New Haven train,

One of the two trucks under the locomotive is shown in Fig. 416. One complete motor mounted on its pair of drivers is shown in Fig. 417. The eyes for the tie rods, three on each side show plainly. On a level with axle are two lugs on each side, through which the four suspension bolts pass.

Fig. 423. Master Controller.

The complete armature with the end plates which support field, are shown in Fig. 418, mounted on the axle. Fig. 419 shows armature with its driving quills. Fig. 420

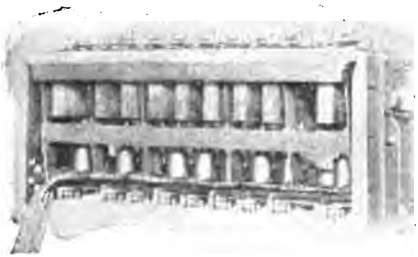

Fig. 424. Unit Switch Group.

shows one driving quill in greater detail. Note the central hole through which locomotive axle passes. The key way to connect armature spider to quill is shown. The

driving pegs of quill are hollow to contain the end thrust springs.

Fig. 421 shows the outside of driver with the driving pegs in the pockets of driver. Two of these pockets have the cover plates in position. Fig. 422 gives the details of the springs.

Fig. 425. Speed Recorder.

Fig. 423 shows the master controller, and Fig. 424 a group of unit switches.

Each locomotive has a speed indicator whose mechanism is shown in Fig. 425. It being a magneto frictionally driven from a locomotive driver.

LESSON 41.

New York Central Motor Cars.

The one hundred and twenty-five steel motor cars of the New York Central are of pressed steel even to doors and window casings and ornamental mouldings. They are 60 feet in length over all with a wheel base of 45 feet.

They are designed to pass around a curve of 135 feet radius.

The light weight of motor cars and trailers is 102,600 and 78,600 lbs. respectively, giving weight per passenger of 1,603 and 1,228 lbs. respectively. The weight of the usual 60 foot wood coach is 61,800 lbs., or 965 lbs. per passenger. In spite of this extra weight the total train of six cars is lighter than a steam train, the gain being due to absence of locomotive weight.

An electric fan is located in each end of car for cooling and ventilating.

The two 200 H. P. motors on the motor truck are controlled by the Sprague-General Electric Type M Control with automatic acceleration at rate of 1¼ miles per hour per second up to a maximum speed of 52 miles an hour.

The arrangement of motor control apparatus is shown in Fig. 426.

When controller is thrown to first notch forward wire number 4 (which will be referred to as W4) and wire number 2 (W2) are energized.

W4 goes through the reverser coils and through coils of contactors 11, 12, 1, 10 and thence to ground. This

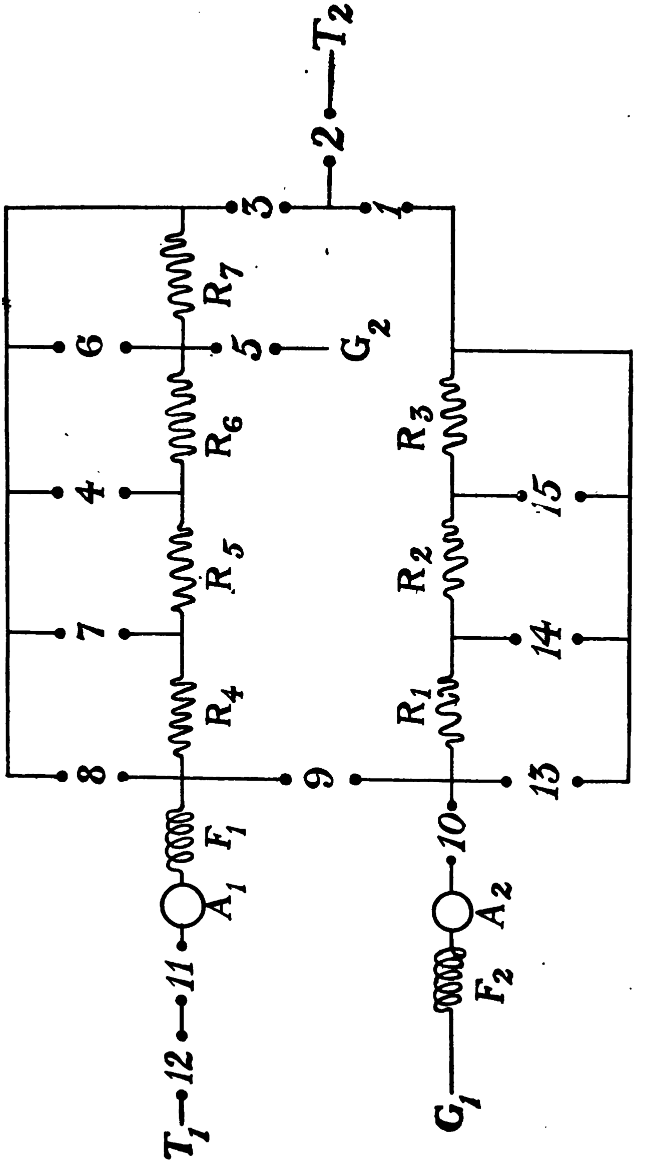

Fig. 426. Diagram of Motor Control, N. Y. C. & H. R. R. R. Motor Car.

swings the reverser into the forward position and closes the four series contactors 11, 12, 1 and 10.

W2 has its circuit closed at controller but completed through the interlock on contactor 12, so coil of contactor 3 is now energized; 3 closes and motors are in series with full resistance.

Turning controller to notch 2 places W1 in service. This is the pick-up wire. It goes to the throttle relay across its disk and up through a magnet which lifts the disk and then on through contactors 13, 6, 8. It does not close all these at once because as it is closing 13 it is also lifting the core of the throttle relay in order to break its own circuit. There is a slip joint between core of magnet and disk on throttle relay so that contactor 13 has time to close and throw its own coil (by means of interlock) over to W2, but contactor 6 does not have time to do this before throttle relay breaks circuit of W1.

The closing of contactor 13 cuts out R_1, R_2 and R_3 so that motors take more current.

It is this increased current passing through the series coil of the throttle relay that holds the disk up, continuing to keep pick-up wire (W1) open circuited until the current through motors dies down to its normal value.

Then throttle relay closes, W1 instantly picks up contactor 6, which itself gets on to W2 before the throttle relay can open W1. The rush of current holds relay up till the current falls again. Contactor 8 is then closed in same way and motors are in full series.

While this has been going on W2 has been trying to close contactors 4 and 7 but could not on account of interlocks until 13 and 6 were closed, then 4 and 7 close in succession and then 8 closes.

While moving from notch 2 to notch 3 the bridge contactor 9 is closed and 3 is opened. This makes no electrical changes, nor does the opening of 8, 7, 4, 6, 13.

When notch 3 is reached W3 is energized and contactors 2 and 5 close. This arrangement is safe because even in the lowest resistance circuit from T_2 to G_2 there is sufficient to prevent a short circuit. However, the closing of 2 and 5 by means of interlocks throws 9 open, placing the motors in parallel with resistance.

At notch 3 wire 1 is not connected, so motors stay in parallel with resistance till controller is moved to notch 4 which cuts in W1; thus starts the automatic closing of contactors. Due to the action of interlocks, when contactors 2 and 5 are closed the order of closing contactors by W1 is to close them by groups, each group awaiting the action of the throttle relay. 6-15-4 close, then 14-7, then 13-8, when the motors are in full parallel with no resistance.

Contactors 11-12-1-10 close when the reverser is thrown and are always closed unless controller is in off position.

The action of contactors for reverse motion is the same, except that W5 closes the contactors 11-12-1-10 and passing through other coil on reverser throws it into the position for backward motion of car.

On the reverse the full series position is as far as the acceleration will progress.

LESSON 42.

NEW YORK CENTRAL LOCOMOTIVES.*

The locomotive, 35 of which are in use on the N. Y. C. & H. R. R. R., weighs about 100 tons and has 71 tons on its drivers. These are four in number, 44 inches in diameter. The driving wheel base is 13 feet.

A Pacific type steam locomotive has three driving axles, with 75 inch drivers, and the same 13 foot wheel base.

The electric and steam locomotives can take same curves, but the electric has the better grip on the rails due to the four driving axles and it has as much weight on drivers as steam locomotive has altogether.

At each end of the locomotive is a swiveling truck with one axle; these axles carry 36 inch wheels. From last driver axle to truck axle is 7 feet and from truck axle to end of locomotive is 5 feet more. This with the 13 foot driving wheel base gives a total length of 37 feet or 30 feet shorter than a steam locomotive.

Each driving axle is 8½ inches in diameter and has keyed to it a sleeve upon which is carried the armature core sleeve and the commutator hub, each separately keyed. The drivers are forced on the axles as usual, forming a rigid and solid unit.

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*To Mr. J. C. Irwin and Mr. S. A. Bickford, both of New York Central, are due thanks for completeness of following information.

Fig. 427 shows one of these units standing inside its field coils with one driver removed to afford a better view.

The top bar is not a mechanical part of the frame, but is one of the two pieces of soft steel, running the length of the motors to improve the conductivity of the magnetic circuit.

Since the commutator ends of the motors are the lighter, these bars lie on that side of the frame, preserving a mechanical balance.

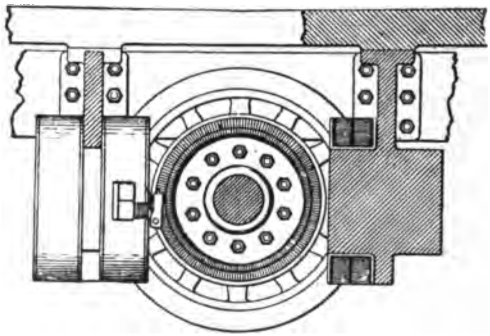


Fig. 427. Locomotive Motor.

This bar shown in Fig. 428 runs the length of the four motors.

In Fig. 427 the broad piece below the bar is the locomotive frame which together with the transoms acts as the main magnetic circuit. The transoms are bolted to the frame as shown.

The five transoms in the middle of the frame carry

bosses which serve as magnet cores and the field coils are placed on them.

The pole face not shown in Fig. 427, but in Fig. 428, is of soft iron sheets held between two heavier end pieces, dove-tailed to the magnet core and keyed. These prevent the field coils from slipping off.

The ordinary motor has a cylindrical pole face, but these are almost flat, so that the armature can stay still on the track and the frame with the poles swing up and

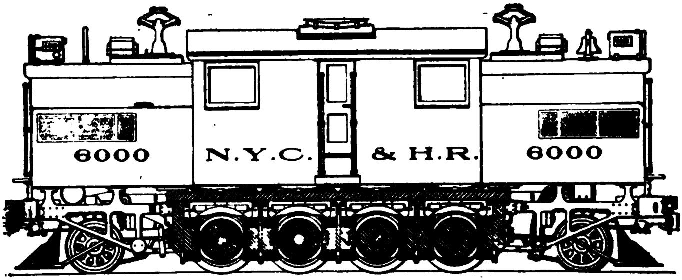


Fig. 428. The First New York Central Locomotive.

down without striking the armature. This shape also makes it possible to drop an armature down into a pit without disturbing the pole faces or field coils.

The brush holders being on the transoms, move up and down with the frame, being kept in contact with the commutator by springs.

The collector shoes are also fastened to the frame, being kept on the third rail by springs.

The field coils are 80 turns of copper ribbon 3 inches

wide insulated by card board. They are wound on a brass spool which is slipped into a shell and the protection completed by riveting the joints and pouring shell full of a bituminous compound.

The journal bearings each have a pedestal resting on them which carries on its upper end a half elliptic spring. The bearings slide in jaws of the frame.

The weight of each pair of drivers, the axle, the complete armature, journal bearing, pedestal and spring rest solidly on the track. The two trucks do the same.

Everything else rests on the frame, and the frame is hung from the springs.

The two trucks and the drivers furnish six axles to support the weight of frame and its load.

Equalizing levers distribute the load properly, and cross equalizers give a three-point support.

The superstructure consists of the cab in the center and two end compartments.

In the center of the cab stands the steam heating apparatus. A kerosene automobile burner heats a coil tube boiler, producing superheated steam. This when passed through a reducing valve furnishes to the train absolutely dry low pressure steam. In this way the size of plant capable of heating a train is reduced to a minimum. The fuel and water pumps are motor driven.

At one end of this heater is the motor driven air compressor. There are two motors on its shaft connected in series. This gives 300 volts per motor and enables them to run at the low speed of 175 R. P. M. The compressor supplies 130 lbs. of air for braking, whistling, bell ringing and sanding. It is regulated by a starting

and stopping switch which is opened and closed by an electro magnet. This magnet is operated by switch opened and closed by the action of the air on a diaphragm. 125 lbs. pressure starts and 135 lbs. stops the motors.

At both corners diagonally opposite are duplicate sets of controlling apparatus. They consist of the controller bar and reverse lever under left hand. In front are the automatic and straight air brakes, the hand sander, the

Fig. 429. Motor Armature.

ammeter and air gauge, and the control circuit switch. At the right hand is the air blast sander, bell and whistle valves.

The end compartments contain a central aisle and on either side in asbestos lined sheet steel cabinets are contained the other apparatus of the control.

Each of these four (two at each end) cabinets contains the resistances and the contactors for one motor. Evenly

distributed among the four are the two reversers, the main power switch, the circuit breaker, the throttle relay, air pressure governor, air sanders, and the contactors for motor combinations.

The lighting and head light switches are in the aisles for ready access.

A view of a complete armature mounted on driving axle is given in Fig. 429.

The locomotive is fitted with the Sprague-General Electric Type M Control with a controlled acceleration.

There is a friction clutch attached to the main shaft of the controller, operated by a magnet. This magnet is in the circuit of wire 18 which also contains a magnetically operated switch.

The operating coil of the switch is a part of the main power circuit leading to motor No. 2.

When the motor is taking less than 900 amperes from the line the magnet is too weak to close the switch, and so the locking coil is not energized, and the controller handle is free to be moved.

Should the motor current rise above 900 amperes the magnet closes the switch, the lock coil throws the clutch and the engineer can not advance the handle until the current falls to its normal value.

Fig. 430 shows the wiring of the four motors, their resistances and contactors as arranged in the New York Central locomotive No. 6000, the first one built.

The terminals marked T are connected to the third rail or "trolley," those marked R to the rails or return circuit, often called "ground."

The armatures are represented by circles and the fields by squares. The resistances are shown by the crooked

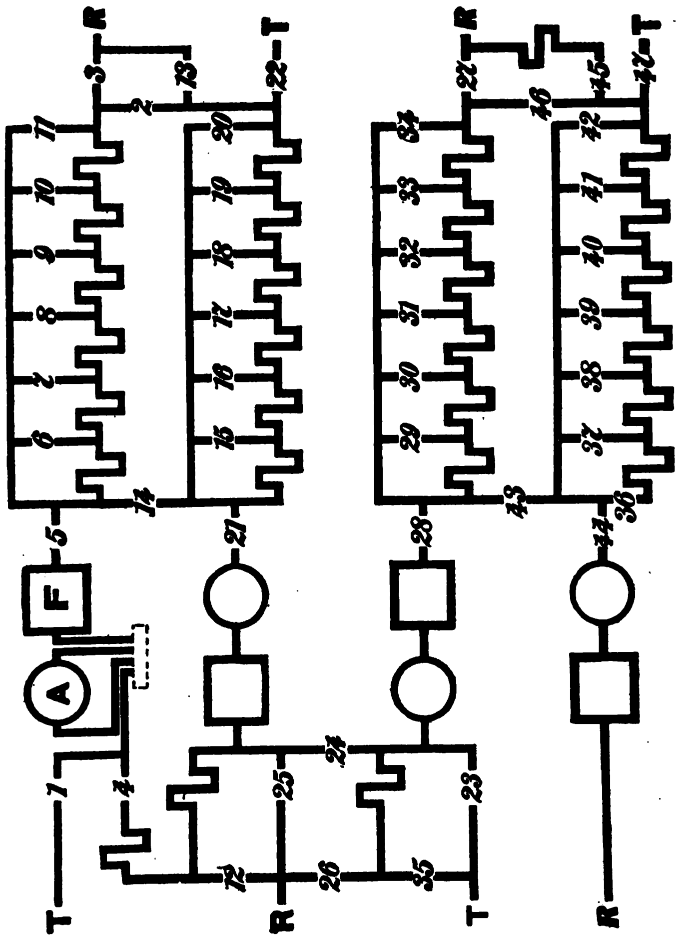


Fig. 430. Diagram of Motor Control New York Central Locomotive.

lines, being a rough imitation of the shape of the cast iron grids used as resistances.

On No. 1 motor at the top has been indicated how the leads go to a reverser, but this has been omitted from the rest of the diagram for the sake of clearness.

Each number represents a *contactor* and when the contactor is closed the gap in the circuit as shown in the diagram is closed and current is permitted to pass.

The wiring which actuates these contactors is called the *control system* and will be the subject of another illustration. This diagram (Fig. 430) only shows the main or power circuits. Each wire in the *control* is numbered and this number is used to refer to it.

The controller which actuates these 47 contactors has 24 positions or *notches* numbered consecutively. Nos. 10, 17 and 24 are running positions, placing the motors at N 10 all in series; at N17 in series-multiple i. e., two in series and two in parallel or multiple; at 24 all in multiple. This gives quarter, half, and full speeds. At all the other notches there is more or less resistance in the circuits, and the controller must not be left permanently at any notch but these three.

The motors are numbered from the top of Fig. 430 down, Nos. 1, 2, 3 and 4. The numbers 1, 2, 3 and 4 after a symbol denote the motor to which the part belongs.

F 1 denotes the field of motor No. 1. R 12 denotes the second resistance (counting from left to right) of the first motor. R 36 denotes last resistance of third motor.

Each motor has a set of six resistance grids whose total for each motor is 0.4 ohm and whose parts have resistances as given in Table A. In Table B is given the resistance left in each motor circuit when the previous grids are cut out.

TABLE A.

Resistance	1=0.120 ohm.
Resistance	2=0.085 ohm.
Resistance	3=0.055 ohm.
Resistance	4=0.050 ohm.
Resistance	5=0.046 ohm.
Resistance	6=0.044 ohm.

TABLE B.

Resistance	1 to end=0.40 ohm.
Resistance	2 to end=0.28 ohm.
Resistance	3 to end=0.195 ohm.
Resistance	4 to end=0.14 ohm.
Resistance	5 to end=0.09 ohm.
Resistance	6 to end=0.044 ohm.

There are four other resistances, one per motor, located as follows:

B 1 between contactor 4 and R.
B 2 between F 2 and 12.
B 3 between A 3 and 35.
B 4 between 45 and R.

These resistances are 0.48 ohm. each. B 2 and B 3 are used as *bridge* resistances to prevent short circuits when changing from slow to middle speed. B 1 and B 4 are used as resistances during electrical braking.

Fig. 431 shows the electrical connections of a locomotive reverser.

The right and left sides are exact duplicates, so only one side will be described.

As shown the S portion of the reverser is shut and the O part is open. The magnets and link bars operating the two pairs of toggles S and O are left out, in order to make diagram simpler.

T represents a tap from the main power cable and may be considered as *"trolley."*

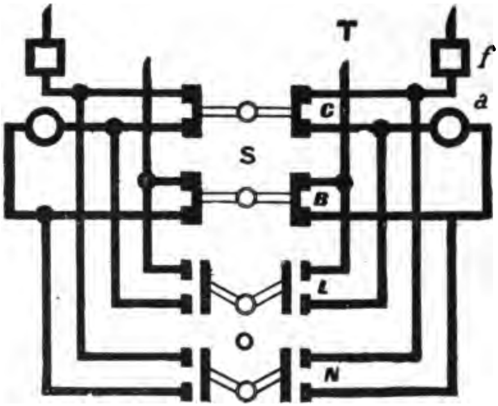


Fig. 431. Diagram of Locomotive Reverser.

The current comes from T goes through B to the armature *a* (circle), thence to C and passes through the field *F* (square). The same thing happens on the other side of S.

If, however, the magnet connected to O is energized, the toggles O will straighten and close the contacts L and N on both sides. The magnet S being interlocked with O is now de-energized and the S toggles loosen and contacts C and B open.

Then the current goes from T to L and through the armature in *opposite* direction than before, thence to N

and through the field in the *same* direction as before. The motor now reverses; for to reverse a motor, reverse the armature or field but not both.

Operation of Control.

Imagine the engineer standing in the cab with the reversing and air wrenches in his hand. The controller levers are not removable and are both in place in the *off* position. In fact they had to be there before the reversing wrench could be removed, and the air brake wrench had to be at lap before it could be taken off. There is but one reverse and one air wrench per locomotive.

He seats himself, puts on the two wrenches and throws the reverse wrench to forward. This puts wire 8 to trolley and ground (T. and R.), and the control current passes through the reverser magnets and pulls both to the forward position.

Wires 51 and 52 now close contactors 1-5-21 and 28-44-36. These are *always* closed while the locomotive is running.

Notch 1 now energizes W 1, closing C 2-24-46, completing a series circuit of the four motors and 1.6 ohms resistance.

For the next nine notches these contactors remain closed and in addition contactors close and open as follows:

Notch 2 energizes W 6, closing C 20, cutting out all of the resistance belonging to M 2 thus reducing the total resistance to 1.2 ohms.*

*By this I mean the **extra** resistance in grids is 1.2 ohms. The resistance of the motors is always present and need not be mentioned each time.

Notch 3 energized W 7, which picks up C 20 (which W 6 no longer holds) and also C 42, which cuts out 0.4 ohms more, reducing resistance to 0.8 ohms.

Notch 4 energizes W 10 which holds up C 20 and 42 and also closes C 34 cutting out 0.4 ohms more.

Notches 5-6-7-8-9: While W10 continues to be energized holding C 20-34-42, wires 11-12-13-14-15 are successively energized closing C 6-7-8-9-10 one after the other. Thus gradually reducing the resistance from 0.4 to 0.044 ohms as shown by Table B. Each contactor stays down until the following one closes.

Notch 10: Wire 16 is energized and W 10 de-energized but C 20-34-42 are held up by W 16 and it picks up C 11 in addition, thus putting the motors in full series between Trolley 1 and Return 4, without resistance. N 10 is a running position at a slow speed.

In moving from N 10 to N 11 many changes occur. W 51 and 52 are of course still working. W 5 cuts in and transfers C 2 and 46 from W 1 to itself, it also closes C 12 and 35. The two bridging resistances B 2 and B 3 being together equal to 0.96 ohms prevent a short circuit from T 3 to R 2.

The circuit containing B 2 is called a *bridge* because it bridges over what would otherwise be an opening in the circuit as the changes occur.

W 1 now drops out of circuit allowing C 24 to open, thus placing two motors in series between T and R.

W 2 now is energized and closes C 25 and 23 cutting out B 2 and B 3 considerably reducing the resistance of each motor combination.

W 10 now closes C 20 and 42 but *not* C 34 as it did before. W 10 can only shut C 34 if C 24 is already closed.

This is due to a system of interlocks. C 24 is now open, for it dropped when we shifted from W 1 to W 5.

The motors are now in series—multiple with half of the resistance in series.

Notches 12 to 17 (both inclusive) energize in succession W 11-12-13-14-15-16 closing C 6 and 29, then C 7 and 30, etc., thus stepping out the remaining resistance until at N 17 we are at a free running position with no resistance in.

Between N 17 and 18 we shift from W 2 to W 3 which performs same duties as W 2 and in addition closes the bridges C 14 and 43. These two contactors produce no electrical changes for the resistances were already cut out entirely by W 16 through the contactors under its control.

W 16 can now be and is dropped without any electrical change. W 4 is now energized closing C 3-22-27-47. There are no short circuits caused because between trolley and return on one side of bridges are the motors and on the other side are the double resistances, each 0.8 ohms.

W 2 is again taken up which takes care of C 24-25 holding them up and W 2 is dropped, letting go of C 14 and 43.

We are now in multiple with resistance in series.

Notches 19 to 24 keep W 2 and 4 energized and successively energize W 11-12-13-14-15-16, closing contactors four at a time, i. e., C 6-15-29-37 then C 7-16-30-38, etc., until finally W 2-4-51-52 and 16 keep the contactors closed for free full multiple running.

The spaces between N 10 and 11; N 17 and 18 are wider than the others to give room for enough motion to make the desired wire changes. These spaces must be passed over by a continuous motion of the controller arm.

Wires 11 to 16 always close contactors four at a time but the first and second times they are used part of the contactors closed produced no electrical changes and for simplicity mention of the fact was omitted.

Contactors 4-26-13-45 are used when braking electrically in this way.

A switch called a commutating switch is thrown and the controller pulled to first notch.

The commutating switch brings in wires 17-4 and 5, W 17 closes contactors 4-13-26-45.

W 4 and W 5 due to interlocks do not close as many contactors as they would if energized through main controller so W 4 only closes 3-27 and W 5 only closes 12.

Notch 1 of controller energizes W 51 and W 52. W 52 as usual closes 28-36-44 while W 51 on account of interlocks only closes 5 and 21. The four motors are now in parallel across the track rails all connection with third rail being cut off. They now act as generators and act as brakes.

This can only be done when one locomotive is on a train else the other locomotive being so near (40 feet) acts as a short circuit.

The one wire not mentioned W 18 is the one called controller lock. It energizes the magnet of the friction clutch through a relay whenever current input exceeds 900 amperes per motor.

Table C gives the number of the control wire, the contactors operated by it, and the notches of the controller making use of the wire.

In this table and elsewhere 1 to 10 means both inclusive and 1-2-10 means separate numbers.

TABLE C.

Notches.	Wires in circuit.	Contactors closed.
All	51	1-5-21
All	52	28-36-44
1 to 10	1	2-24-46
2	6	20
3	7	20-42
4 to 9	10	20-42-34
11 to 16	10 (interlock)	20-42
5-12-19	11	6-15-29-37
6-13-20	12	7-16-30-38
7-14-21	13	8-17-31-39
8-15-22	14	9-18-32-40
9-16-23	15	10-19-33-41
10-17-24	16	11-20-34-42
11 to 17 } 18 to 24 }	2	25-23
11 to 17	5	12-35-2-46
Between } 17 & 18 }	3	14-43-25-23
18 to 24	4	3-22-27-47

Reverse lever.

Forward	8	Reverser forward.
Backward	0	Reverser backward.
Braking	17	4-13-26-45
Braking	51-(Interlock)	5-21
Braking	52	44-36-28
Braking	4-(Interlock)	3-27
Braking	5-(Interlock)	12
Trolley wire	18	Controller lock coil.

This table will enable you to find what groups of contactors go into operation at same time.

It being found that electrical braking when two locomotives were being operated was useless it was cut out of the equipments delivered to the Central.

Changes in the numbering of the contactors were also made, but the method of control is the same. This lesson will enable the student to get information from the wiring diagram given in connection with the catechism on the locomotives.

LESSON 43.

ROLLING STOCK.

The electric locomotive as a slow speed, heavy load tractor is quite old and there are many of them doing good service to-day that were built ten years ago.

Fig. 432 is in use by the American Bridge Co. Fig. 433 is used in the works of the Westinghouse Electric Co. Fig. 434 is in use in a lumber mill. Fig. 435 is used to haul scrap and pig iron. Fig. 436 is used by the Maryland Steel Co. to haul ingots and moulds. Fig. 437 is in use in Hawaiian Islands.

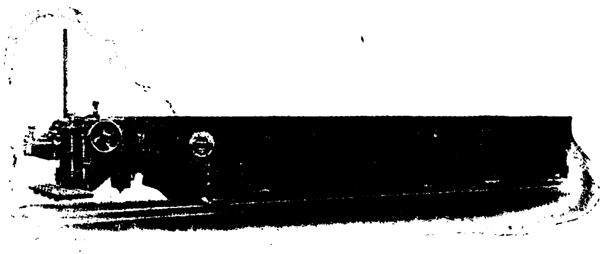


Fig. 432. 10,000-Pound Locomotive.

Fig. 438 shows how standard motors can be adopted to narrow gauge locomotive.

Figs. 439, 440 and 441 show conventional types of higher speed locomotives the latter showing the use of two trolleys allowing the collection of larger currents

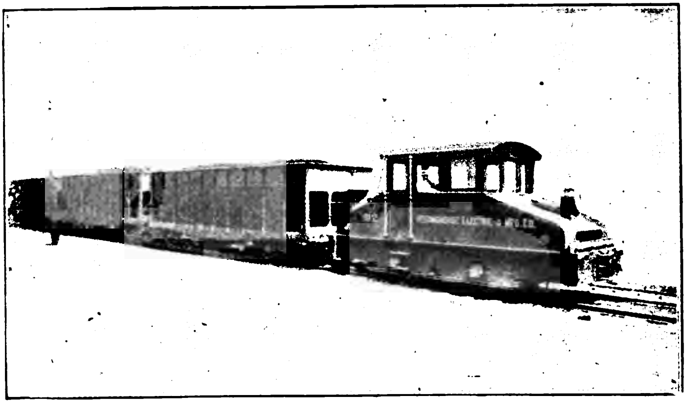


Fig. 433. 95,000-Pound Locomotive.

Fig. 434. 2,600-Pound Locomotive.

without too great a resistance and sparking at trolley wheel.

Fig. 442 shows a 560 H. P. locomotive operating along the Hudson River steamship wharfs. Gear reduction is 3:1. It makes 8 miles an hour.

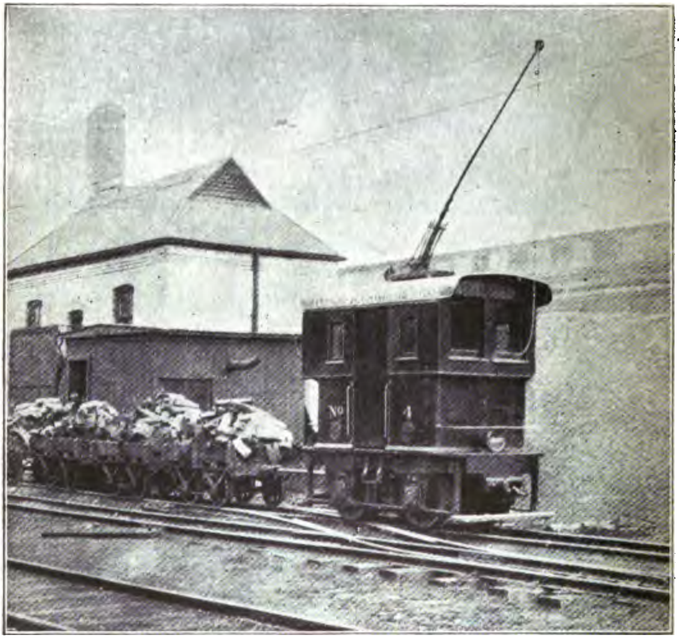


Fig. 435. 8,000-Pound Locomotive.

Fig. 443 shows an American locomotive operating in the Austerlitz Station of the Paris-Orlean R. R. The same locomtives also haul 160 ton trains under Paris in a tunnel to the Quai d'Orsay terminal.

Fig. 436. 10,000-Pound Locomotive.

Fig. 437. 19,000-Pound Locomotive.

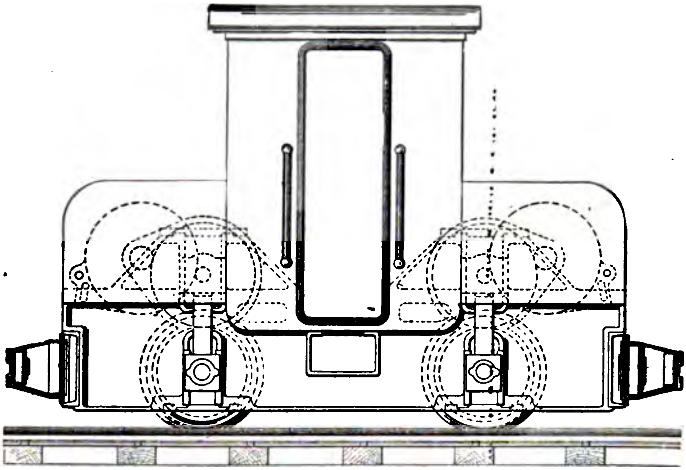


Fig. 438. Special Design for Using Very Large Motors on Narrow Gauge Track.

Fig. 439. 45,000-Pound Locomotive.

Fig. 444 shows the locomotive of the Buffalo & Lockport R. R., designed to handle freight and passenger service between these stations. They are equipped with motors capable of developing 600 H. P. Owing to slow speeds required (15 miles per hour) the motors are connected two in series permanently. They start with all

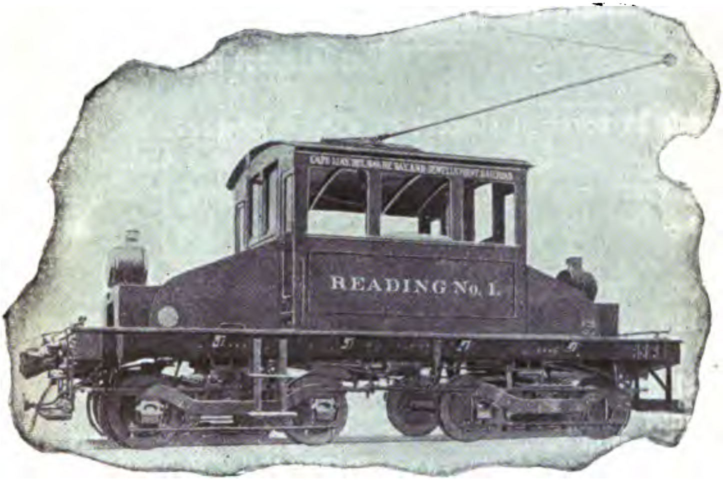


Fig. 440. 47,000-Pound Locomotive.

four in series and then place them in series parallel. They draw 500 amperes while accelerating a 450 ton train up to 14 miles an hour.

Fig. 445 shows a locomotive used in factory yard to drill freight cars.

The Baltimore & Ohio R. R. has been using 87 ton electric locomotives to haul its steam trains (locomotive and all) through the tunnel under the city of Baltimore.

Fig. 441. 55,000-Pound Locomotive.

Fig. 442. Steamship Connecting R. R. Draw-Bar Pull at 8 M. P. H. 10,000 Pounds.

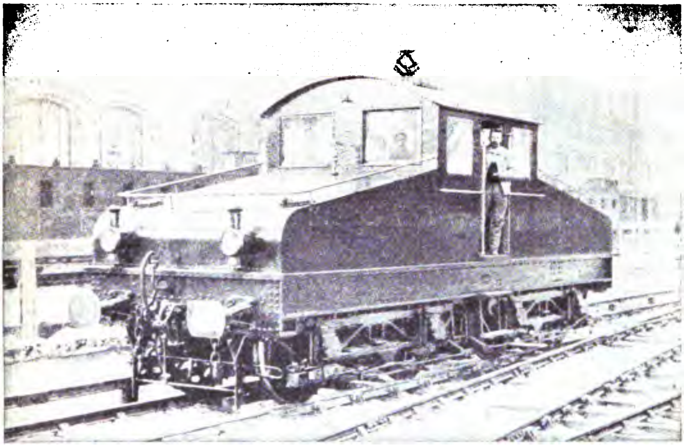


Fig. 443. Electric Locomotive at Austerlitz Station. Paris and Orleans R. R.

Fig. 444. Buffalo and Lockport Locomotive.

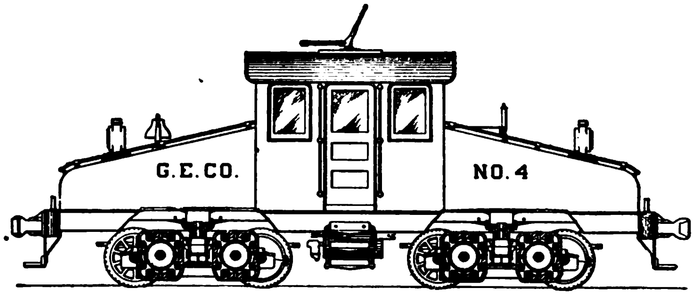


Fig. 445. Factory Yard Locomotive.

Fig. 446. B. & O. Gearless Locomotive.

One of these locomotives is shown in Fig. 446. Three we put in service in 1896 and for ten years have given good service: They will each haul a 2300 ton freight at 10 miles an hour, or a 500 ton passenger train at 35 miles an hour. They draw 2200 amperes at 625 volts during acceleration, dropping to 1800 at full speed.

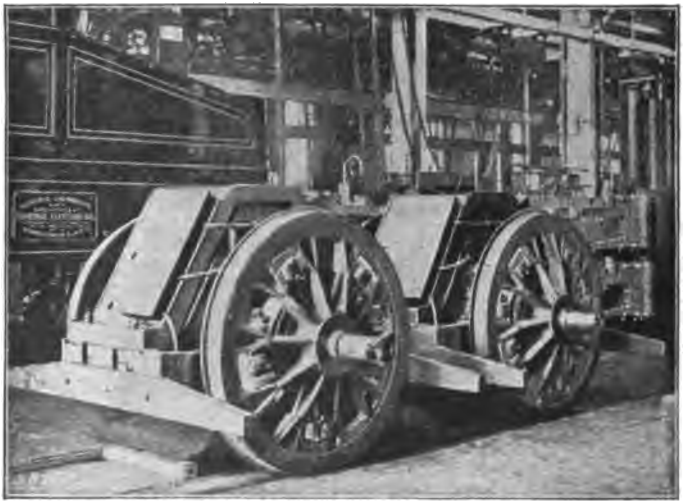


Fig. 447a. B. & O. Locomotive Truck.

One of the two trucks is shown in Fig. 447. The motors are six pole and connected directly to axle. There are two motors in each truck making four in all.

In 1903 the B. & O. put in service two more locomotives. Each one is composed of two units. Each unit contains four motors, each geared to one of the axles by a 4:1 gear. The motors are 4 pole. Each unit weighs 73

tons. Thus the whole locomotive of 146 tons has 1600 horse power.

The geared type is perhaps best for such slow speed work.

Fig. 447b. B. & O. Locomotive Frame and Cab.

The freight locomotive of to-day will be a 16 wheel locomotive of the 0-16-0 type with a joint in the center of its frame like a Mallet Compound. This is called an articulated frame.

Each axle will have its motor. Its general dimensions are shown in Fig. 448.

A New York Central locomotive drawing a train is shown in Fig. 449.

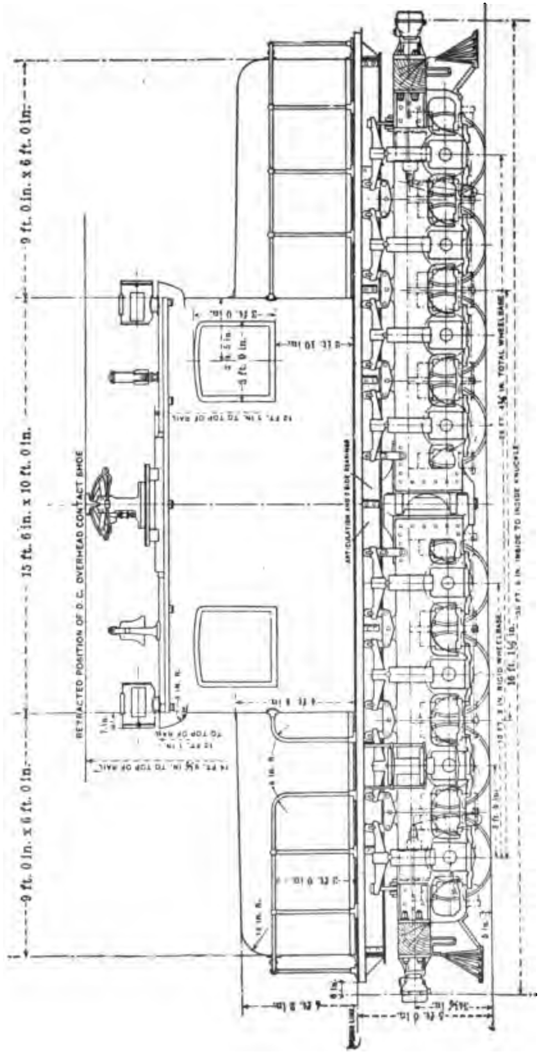


Fig. 448. Typical Freight Locomotive of 0-8-8-0 Type.

Fire proof cars are a very valuable asset to a road, as a means of gaining public favor and their actual calming influence in case of not only slight fires due to electrical troubles but also in slight collisions. Figs. 450 and 451 show a fire proof car designed by Mr. Gibbs. The Erie railroad is using similar ones for Postal Service. The Interborough Co. is using the Gibbs car for motor cars.

Fig. 449. New York Central Locomotive with Train.

These are finished inside with dark green enamel and aluminum paint which although a little hard looking makes a good appearance.

Fig. 452 shows a train on the West Shore R. R. operating between Utica and Syracuse.

Fig. 453 shows a locomotive and Fig. 454 a motor car of the Valtellina Rail Road of Italy. This is a 3 phase equipment.

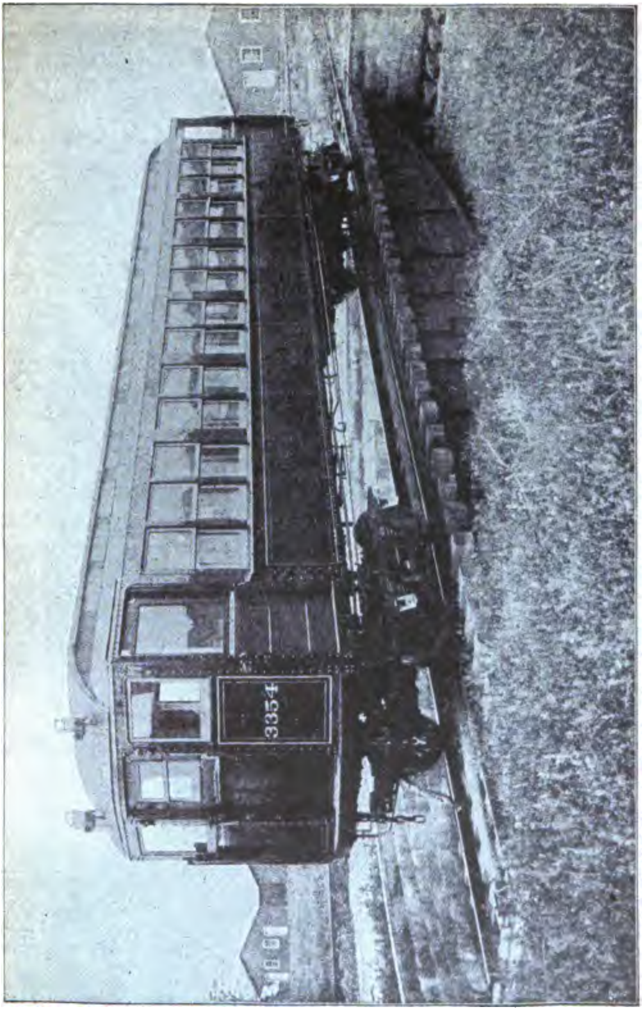


Fig. 450. Gibbs' Fire-Proof Car. Long Island R. R. and New York Subway.

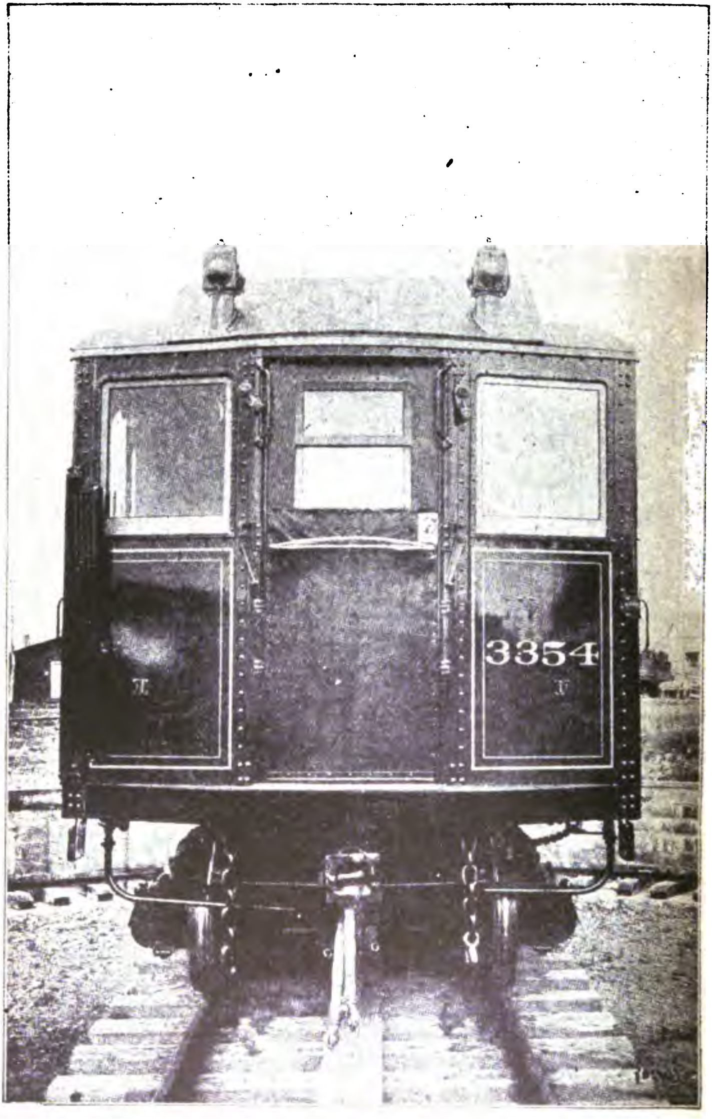


Fig. 451. End View of Fire-Proof Car.

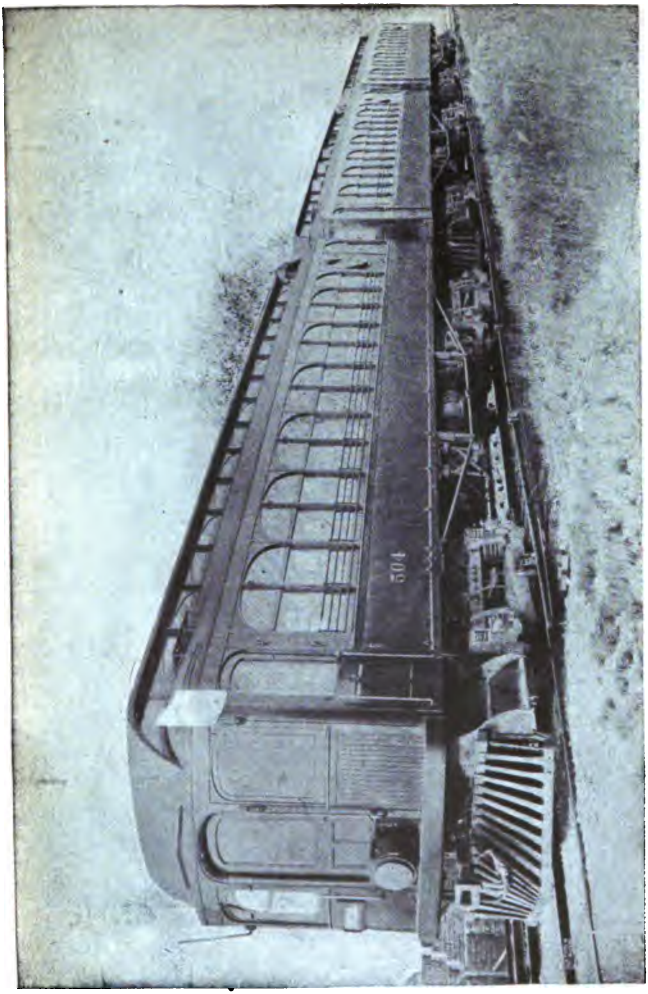


Fig. 452. West Shore Motor Car Train.

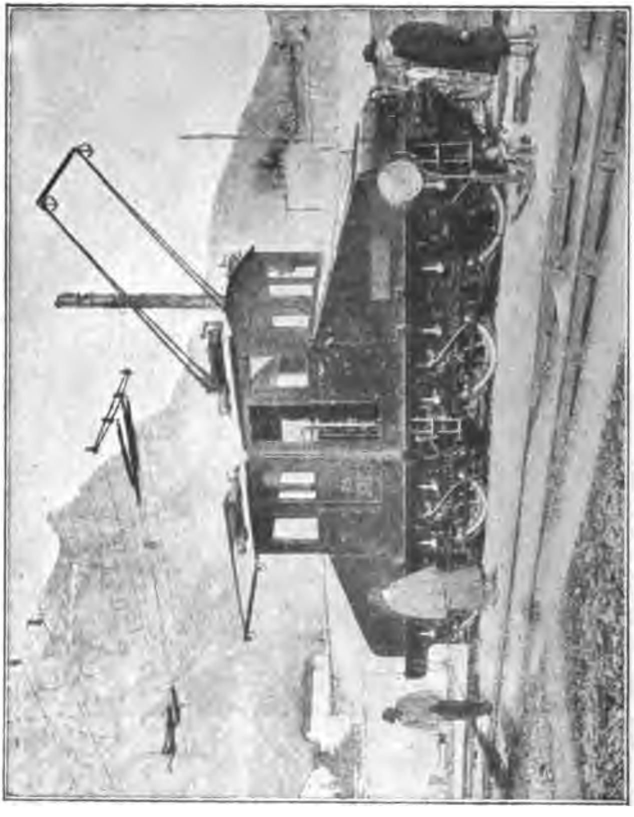


Fig. 453. Valtellina Three-Phase Locomotive.

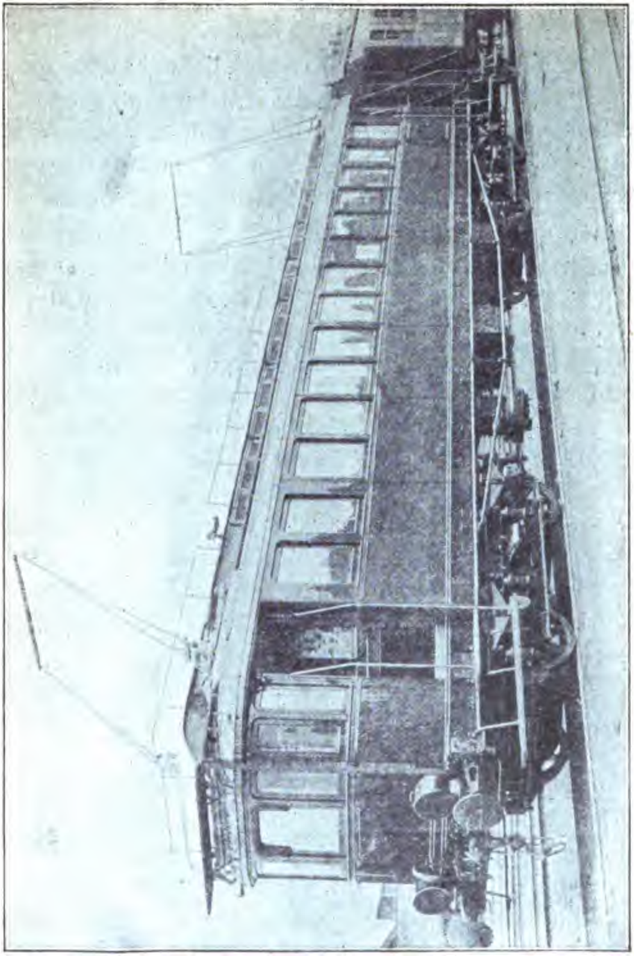


Fig. 454. Valtellina Three-Phase Motor Car.

Trucks.

While the size of motors has been limited by the gauge of the rails, yet the demand for larger horse powers has influenced truck builders to put 36 inch wheels on the motor trucks. Such trucks will soon be standard for steam road work. The trailer truck at other end of car will have 33 inch wheels as standard.

Fig. 455 shows the general dimensions of a motor made for a 33 inch wheel truck. It will be noticed that the car axle goes through a set of bearings on the side of the motor frame. The large gear is fastened to the car. The motor shaft runs in bearings at either end of the frame. The pinion on motor shaft engages with gear on car axle.

Some of the weight of motor is given to car axle by the bearings in motor frame through which this axle passes. The rest is transferred through the truck frame.

Any motion of the motor must be in a circular arc around the car axle as a center, for the distance between center of car axle and motor shaft must always be same, else gear teeth will bind.

The Master Car Builders Association has given its sanction to certain constructions which are familiarly known by the initials, M. C. B.

A truck called the "M. C. B. equalizing truck" is shown in Fig. 456. The center pin is shown on center transom with bearing plates on either side. Outside of these are the side bearings to catch the weight when car rolls. Any up and down motion due to compressing the springs should not bring side bearing plates into contact. They generally come into contact when rounding curves, and to prevent interference with swiveling of trucks under

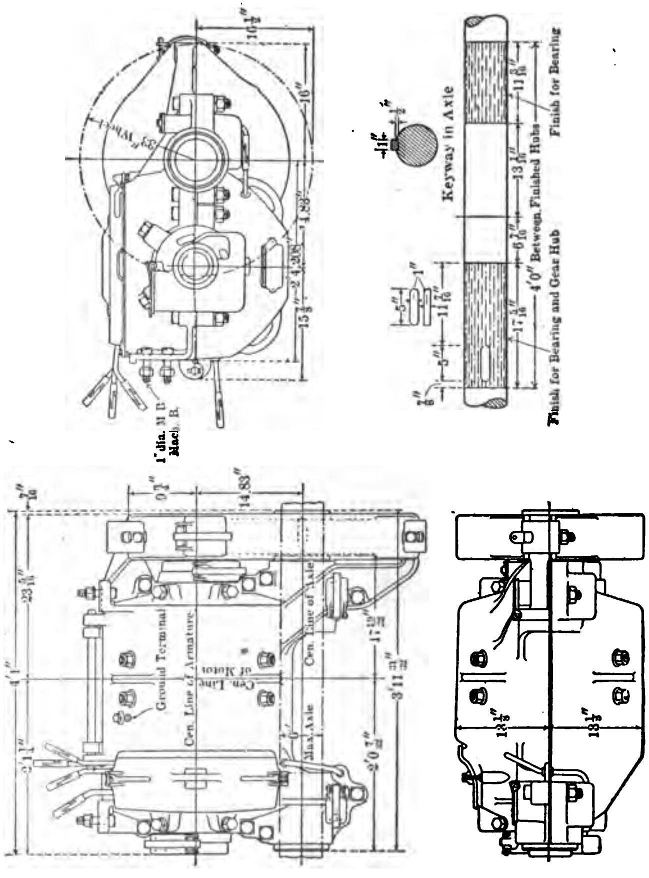


Fig. 455. General Dimensions of Railway Motor.

these circumstances, these bearings are frequently made with rollers.

In the plan view of Fig. 456 only one motor is shown to give a clearer view of the motor suspension. A rec-

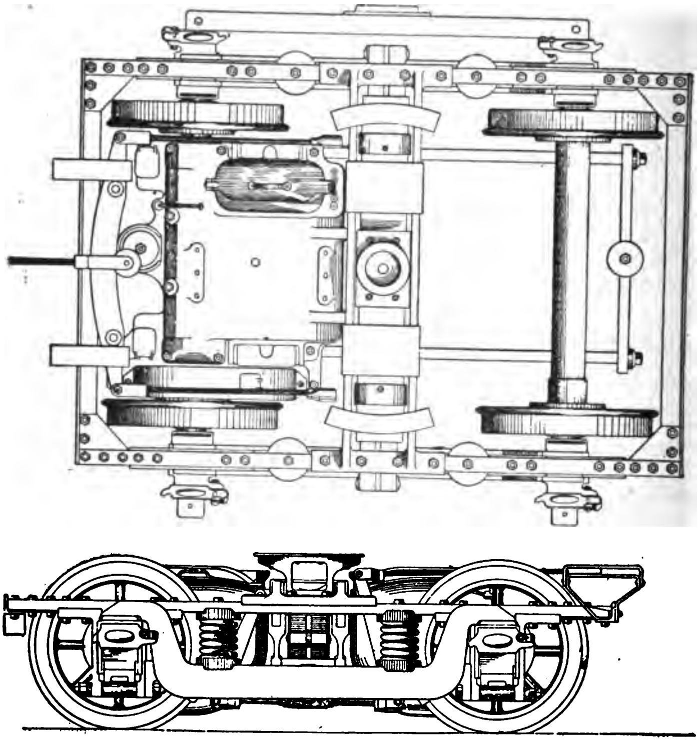


Fig. 456. M. C. B. Electric Truck. Cradle Suspension.

tangular frame of iron bars is hung by the centers of its shorter sides at each end of the truck. The connecting bolt at the same time compressing a spiral spring. On

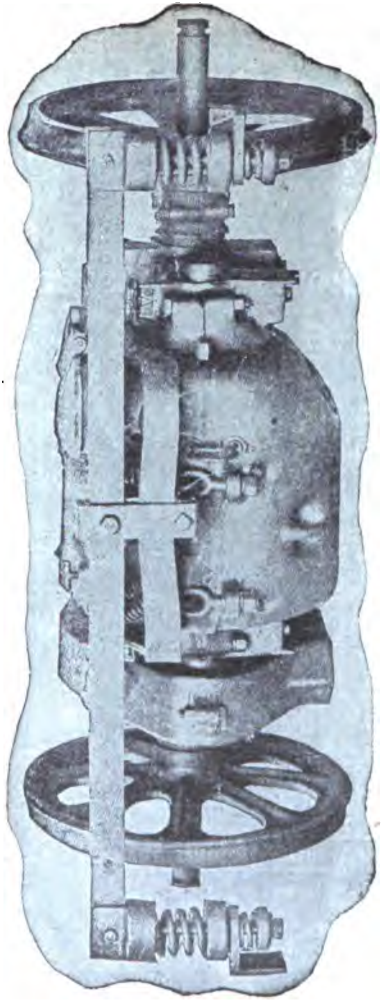


Fig. 457. Cradle Suspension.

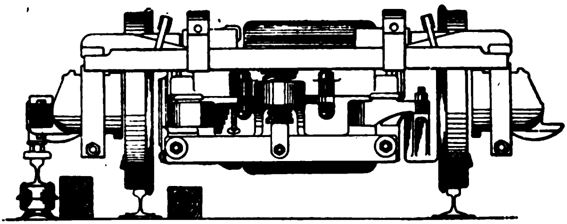


Fig. 458. Gibbs' Cradle Suspension, End View.

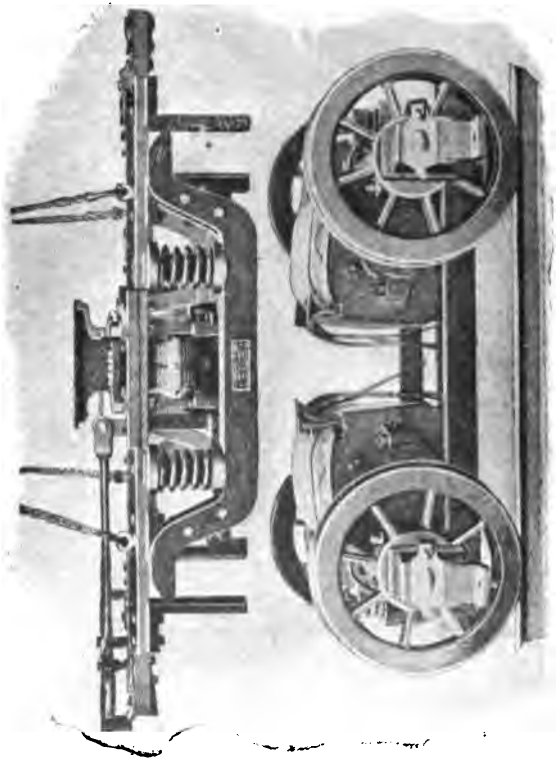


Fig. 459. Gibbs' Cradle Suspension with Truck Frame Lifted.

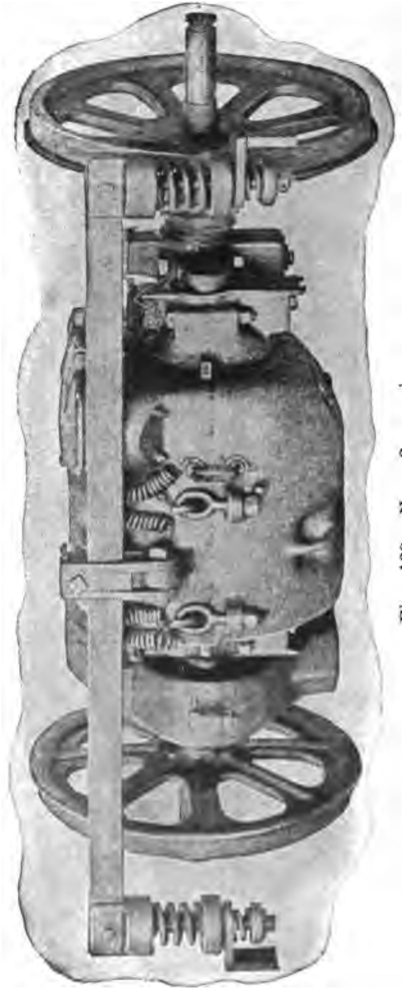


Fig. 460. Nose Suspension.

each side of the motor is a lug which is bolted to the long or side bars of this frame.

This suspension is the *cradle* suspension. It has many modifications. In Fig. 457 the center of end bar of cradle is slung without springs from a cross bar which is spring borne at the outside of the frame.

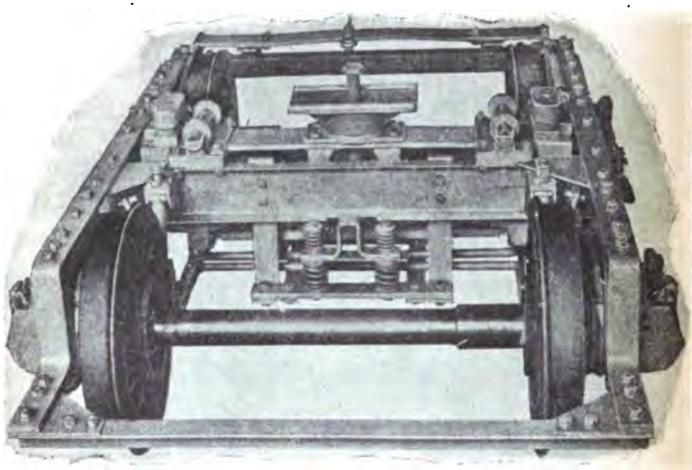


Fig. 461. Nose Suspension.

One of the best cradle suspensions is the Gibbs (Fig. 458) as shown in Fig. 459 the whole truck frame of a M C B truck may be hoisted clear of the wheels and motors.

The nose suspension is simpler than the cradle. The end of motor not resting on car axle is hung from a spring borne cross bar. See Fig. 460.

Another very simple nose suspension is shown in Fig. 461 where the truck transom has a frame bolted to it con-

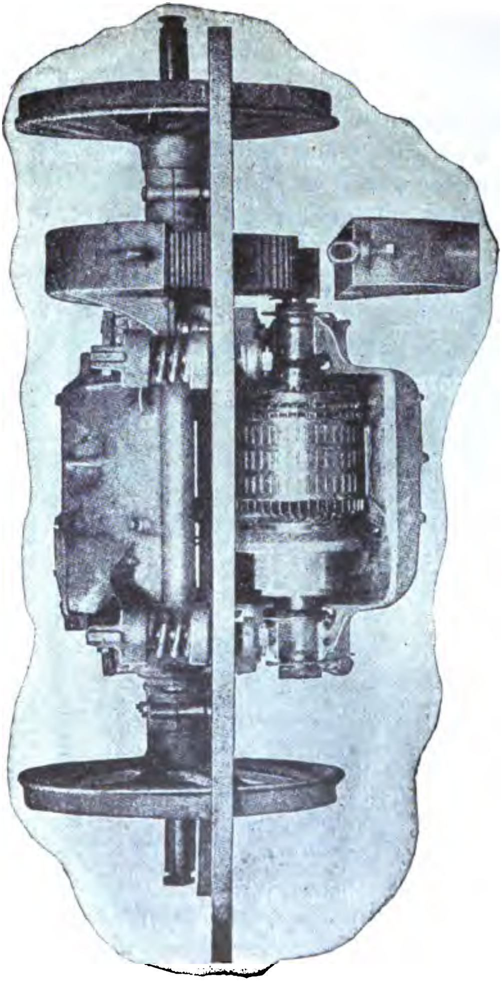


Fig. 462. Parallel Bar Suspension.

taining a spring supported U or loop. A lug or nose on the motor sticks into this U. This illustration shows the king pin, bearing plate, and side bearings all mounted on transom.

Fig. 462 shows a suspension made of two bars running length-wise of truck which hold the motors. These bars are each spring borne at ends of truck, directly from frame. In the illustration two long bars are supporting the parallel bars because there is no truck there to do it. Such a suspension needs four spring supports and is no more flexible than the cradle suspension using only two. It is called the *parallel bar suspension.*

LESSON 44.

Car Equipment.

The electrical equipment of a car consists of the motor truck, the controller, resistances, iron pipe conduits containing the motor circuits, and the motor control circuits,

Fig. 463. Lightning Arresters.

a trolley or set of third rail shoes and a few auxiliary pieces of apparatus. Some arresters are shown in Fig. 463. An arrester installed with a kicking coil is shown

in Fig. 464. A switch called a canopy switch is shown in Fig. 465. It is mostly used in interurban cars where the motorman's cab is built on front platform and this switch is installed over his head: It is a snap break switch and is used to cut off current from car at base of trolley.

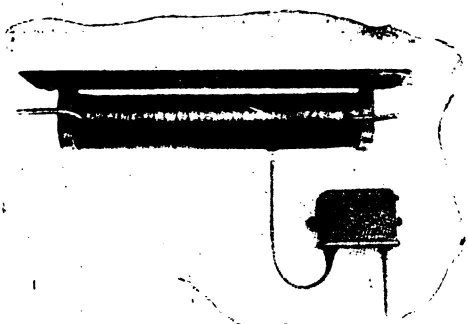


Fig. 464. Choke Coil and Lightning Arrester.

Fig. 465. Canopy Switch to Cut Off Current at Base of Trolley.

When a canopy switch has a magnet trip operated by current to motors it is called a current breaker. The one in Fig. 466 has a magnetic blow-out, which expels the arc through the chute shown on right side. The button on

front is to trip the breaker. The handle on top is for closing it.

Main fuses (Fig. 467) should be protected by iron cases but wood boxes are still used.

Fig. 466. Automatic Circuit Breaker.

Fig. 467. Fuse Block.

Fig. 468. Snap Switch for Lighting Circuits.

The car and vestibule lights are controlled by snap switches on porcelain bases, enclosed by porcelain or iron covers (Fig. 468). Head lights have same style switches of heavier construction.

Contact Devices.

The type of trolley with a wheel to collect current from wire is not satisfactory for high speeds. The wheel is apt

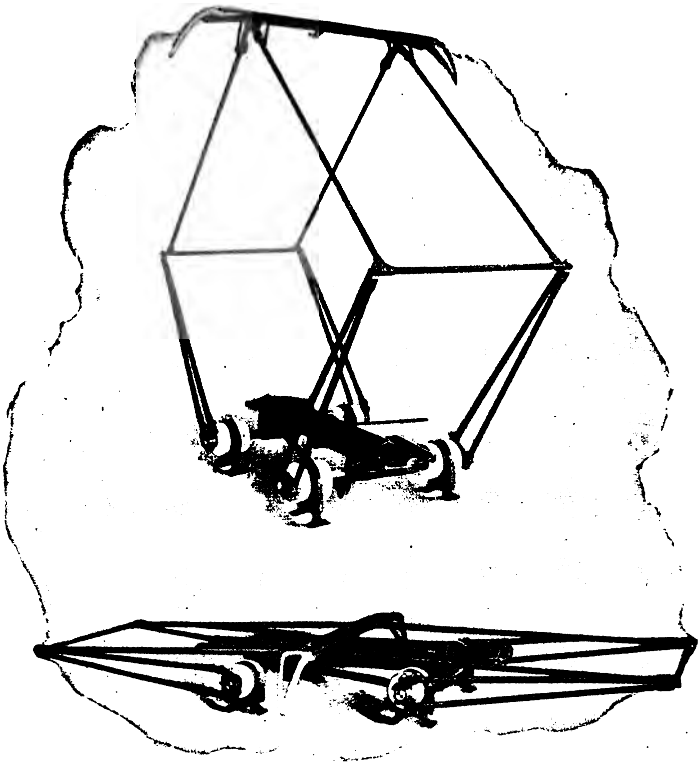


Fig. 469. Pantagraph Bow Trolley. Raised and Lowered.

to jump the trolley wire and smash the guy wires of ordinary, or the braces of catenary construction.

A bow trolley where the wheel is replaced by a broad plate of copper or iron some two or three feet wide and

three inches across, must be used for high speeds. Then no matter how the train sways the trolley and wire always keep in contact.

The latest form of bow trolley is called The Pantagraph Trolley, as shown in Fig. 469. It is raised and lowered by an air cylinder shown in center.

Fig. 470. Third Rail Shoes.

When a third rail is used shoes as in Fig. 470 are the current collectors. These are of cast iron pressed by springs against the top or bottom of the third rail.

Heaters.

In trains of motor cars the only way to heat cars is by resistances made hot by electric current. This is the most expensive way to heat and in interurban cars where motorman is always on front platform (the cars passing around a loop at each end of route) it is better to install a hot air or hot water heater and let motorman attend to it. This can be done at terminals and at turnouts or even at stops where eight or ten passengers are being let off or taken on.

When electric locomotives are drawing the standard railway coach, steam must be furnished. To do this steam heating plants with kerosene blue flame burners are placed in locomotives and attendance given by the second man in the cab.

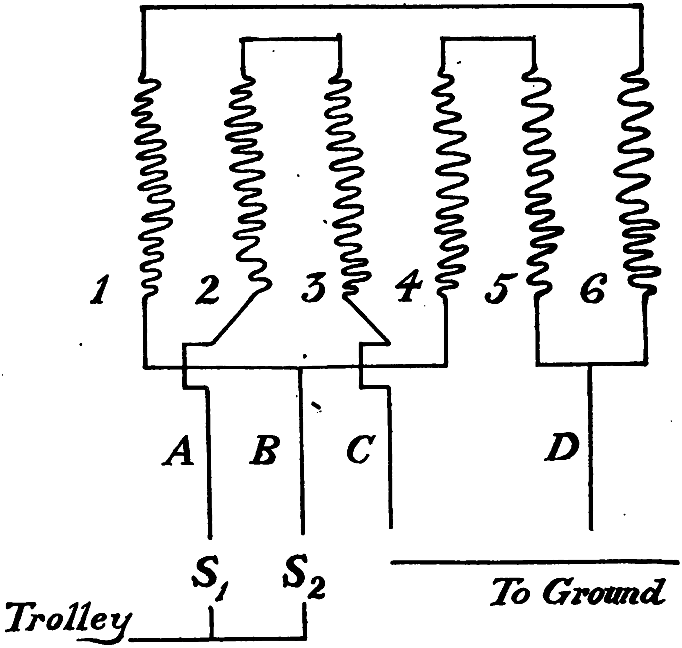


Fig. 471. Diagram of Car Heater Connections.

To furnish two degrees of temperature with electric heaters the heaters although all placed in series, are each individually connected as in Fig. 471.

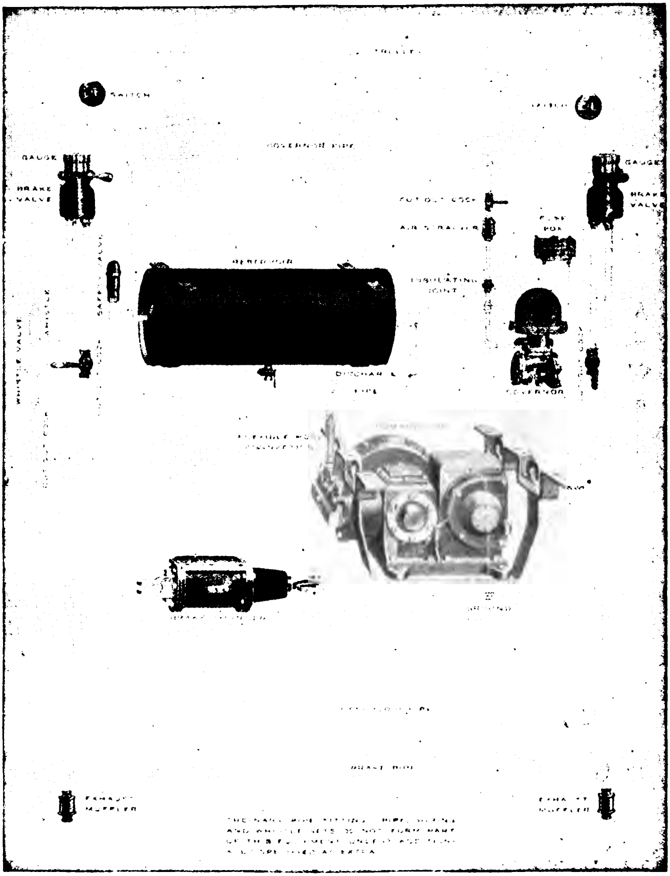


Fig. 472. Car Equipment Straight Air Brake.

Terminals A, B, are connected to the same lettered terminal of heater behind; C and D are connected to C and D of heater ahead.

The first heater has A and B connected to switches S_1 and S_2 which are connected to trolley. The last heater has C and D connected to a ground wire which is connected to some part of frame of truck.

If with switch S_1 closed a certain amount of heat is generated, with S_2 closed twice the heat is obtained, while with both closed the maximum heat is obtained, being three times that given by the switch S_1 alone.

Air Brake.

For complete description of all air brake equipment read Vol. III.

Suburban lines feeding steam roads usually run single cars which are fitted with a straight air equipment like Fig. 472.

The electric locomotives of the New York Central R. R. have the Westinghouse E-T equipment.

Practically all the motor car of railway coach type running in trains have the regular automatic air brake with an air compressor on each motor car.

The parts of such a compressor are shown in Fig. 473, the complete compressor in Fig. 474, and a side view of compressor in its suspension is given in Fig. 475.

The New York Central motor cars have a governor of type shown in Fig. 472.

The New York Central locomotives and the Pennsylvania motor cars have a governor as in Figs. 476 and 477. Showing it closed and open.

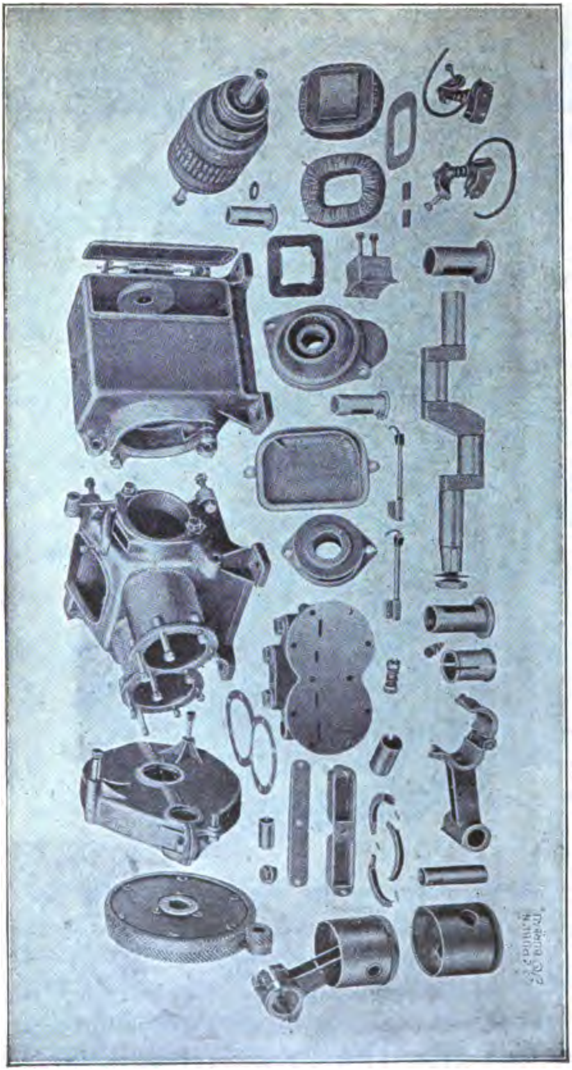


Fig. 473. Parts of Motor Driven (Geared) Air Compressor.

The construction is shown in Figs. 478 and 520. The cylinder head is provided with a tapped hole for the insulated pipe which makes connection between the governor and the compressor reservoir. The head is so con-

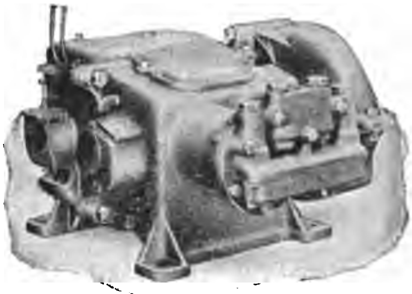


Fig. 474. Motor Driven (Geared) Air Compressor.

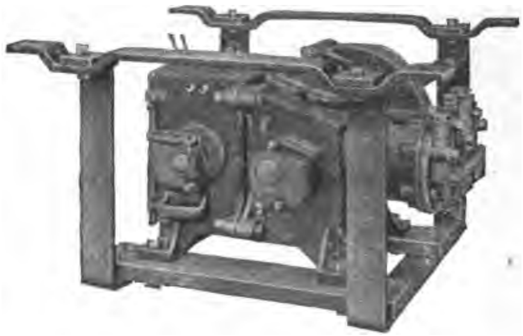


Fig. 475. Air Compressor (Fig. 474) in Suspension.

structed that this connection may be placed at the back or at either side of the governor, as desired. It is bolted to the frame and holds the rubber diaphragm A against the retaining ring. This ring serves as an abutment for

the piston B against the upper surface of which the diaphragm A is pressed. The lower side of the piston is acted upon by the operating spring C, the pressure of which is adjusted by means of the screws R bearing against the washer S. Attached rigidly to the piston B is the rod D, the lower end of which is connected to one of the operating levers. The largest of these levers is

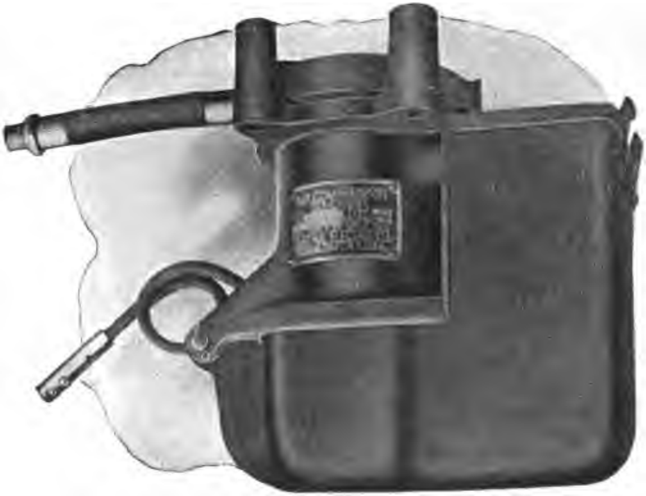


Fig. 476. Air Compressor Governor, Case Closed.

provided with a recess into which a mica insulated stud has been forced by hydraulic pressure. Attached to the stud are the cable terminal and the spring carrying the contact finger. The finger tip through which the circuit is completed and broken is so made as to be readily renewable when worn. This finger completes the circuit

through the stationary contact, the tip of which is also renewable. Enclosing these contact members is the arc chute, which is composed of a special molded insulating compound and is provided with renewable plates of a highly refractory material. This material has the prop-

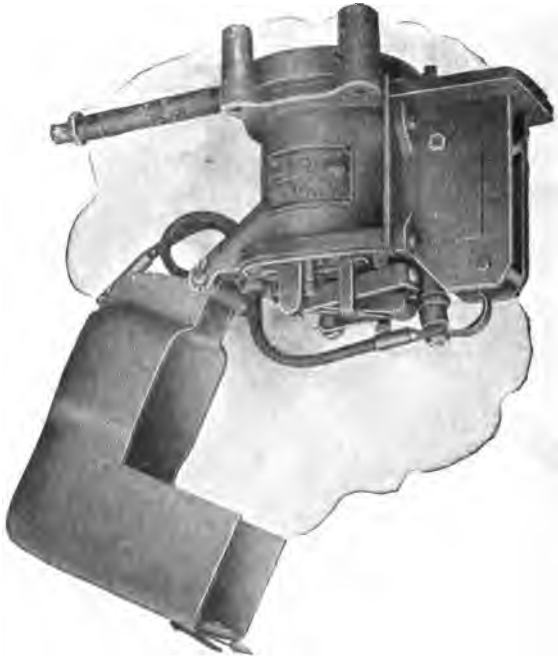


Fig. 477. Air Compressor Governor, Case Opened.

erty of resisting the action of the electric arc to a great degree. In series with this circuit is the blow-out coil O, for producing the magnetic field which extinguishes the arc when the circuit is broken. This coil is made of

enameled copper ribbon wound edgewise, and connected with it is the line terminal, which is provided with two set screws for clamping the wire. The protecting cover is hinged at the back of the frame and is held in the

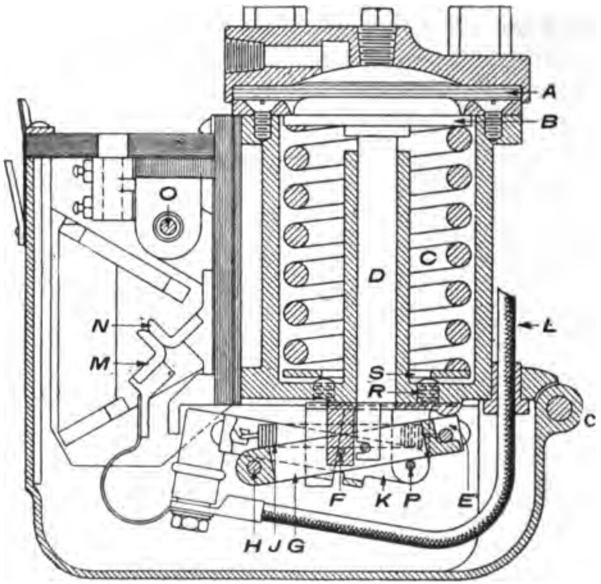


Fig. 478. Construction of Air Compressor Governor.

closed position by a spring catch. On the inside of this cover adjacent to the arc chute is a plate of insulating material which prevents the possibility of the arc striking the metal.

Operation.

The action of this governor in opening and closing the motor circuit of the compressor is as follows:

As the compressor continues to operate, thereby increasing the pressure of air in the reservoir, the pressure in the chamber above the diaphragm A rises and forces the piston rod downward against the action of the operating spring C, turning the lever E around its fulcrum F. This brings the pivot H above the centre line of the tension springs J, which connect the intermediate lever G with contact carrying lever K. The action of these springs then pulls the end of the intermediate lever downward; this movement quickly carries the centre line of the springs past the pivot P, thus reversing the action of these springs on the contact carrying K, and causing the free end of this lever to be drawn downward, separating the contacts M and N with a quick snap.

The object of this double system of levers is to maintain a constant pressure between the contacts until the tripping point is reached, thus preventing burning of the contacts.

As the pressure in the reservoir is reduced the piston rod O raises the rear end of the lever E, a projection of which engages with the intermediate lever G. This carries the center line of the tension springs J above the pivot of the contact carrying lever K and thereby pulls the contact finger upward, quickly closing the circuit.

The information given here is the same as that which the Pennsylvania R. R. demands that the motor-men should know before operating its trains.

The following pages contain a description of the electrical apparatus used on the motor cars of the West Jersey and Seashore R. R., one of the Pennsylvania lines running from Philadelphia to Atlantic City. This road is practically a straight line between the two cities with no grades worth mentioning. It is 60 miles long and can be done by express trains in very little over an hour.

These conditions while ideal for steam locomotives are even yet more suitable for electric traction. When it comes to local trains the electric cars are vastly superior and can make much better time with increased economy.

INSTRUCTIONS FOR THE OPERATION OF MULTIPLE UNIT CONTROL.

GENERAL DESCRIPTION OF APPARATUS.

1. THE MOTOR CARS ON THE WEST JERSEY AND SEASHORE RAILROAD are equipped with two General Electric (No. 69-C) 200 horse power railway motors, both of which are mounted on one truck, known as the MOTOR TRUCK. The Sprague-General Electric (type M) multiple unit system of control is used.

2. BY MULTIPLE UNIT CONTROL is meant the operation of a train of two or more motor cars from a single master controller on any car in the train; that is, a train of several cars, each propelled independently by its own motors, is controlled as one car.

3. THERE ARE TWO CONTROL CIRCUITS on each car: First, the MASTER CONTROL, which is operated by the motorman; second, the MOTOR CONTROL, which depends for its operation on the master control. Both master control and motor control cables are enclosed in iron pipe conduit.

4. EACH MOTOR CAR is provided with two master controllers, one at each end of the car in the motorman's compartment. All master controllers are connected to a seven-wire TRAIN CABLE running the entire length of each car and connected together between cars by the TRAIN CABLE JUMPER. Current received through the master controller and train cable

operates electrically controlled switches known as CONTACTORS on each car, and establishes the motor control on their respective cars. The motor control is local with each car and can be governed by any master controller on the train.

5. EACH MOTOR CAR TAKES CURRENT from the third rail, through the third rail shoes, or from the trolley wire, through the trolley. All third rail shoes and trolleys are connected through switches to a BUS LINE, which runs the entire length of each car and is connected together between the cars by the BUS LINE JUMPER; therefore, if any third rail shoe or trolley is in contact with the third rail or trolley wire, all motors of the train can be supplied with current through the bus line.

MOTOR CONTROL.

6. THE MOTOR CONTROL CIRCUIT (Fig. 479) is the circuit forming the path of the current from the third rail shoes or trolley through the motor control apparatus and motors to the track rails, and is THE MAIN CIRCUIT.

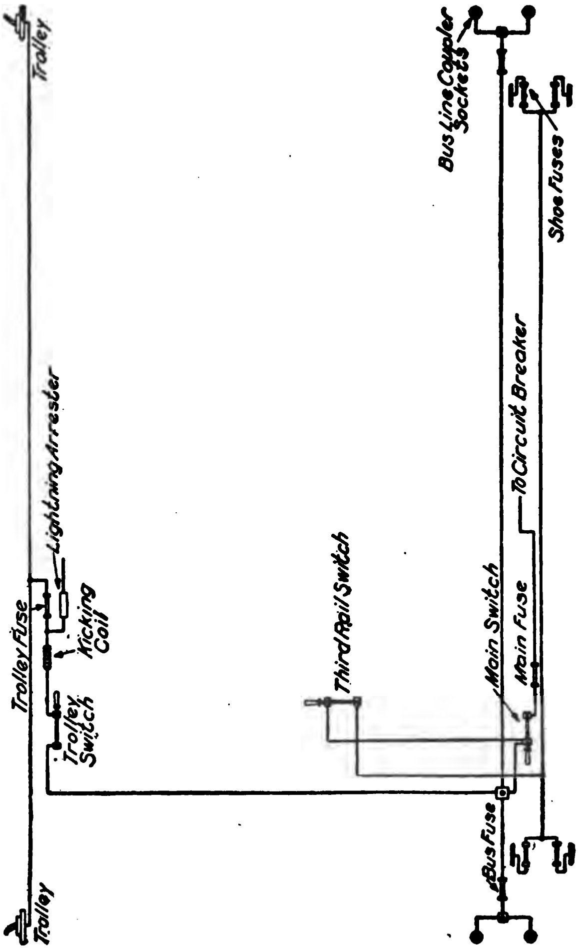
7. THE ESSENTIAL PARTS of the motor control of each car comprise the following apparatus:

One set of fifteen CONTACTORS, which close and open the circuit to the motors.

One REVERSER, which determines the direction of train movement.

One set of eight RESISTANCES, which limit the flow of current to the motors when starting.

PLATE No. 1.



General Arrangement of Motor Control Wiring.

Fig. 479.

ONE CIRCUIT BREAKER, which protects the motors and motor control apparatus against excessive current.

ONE MAIN FUSE, which—like the circuit breaker, and in addition to it—protects the motors and motor control apparatus against overload in case circuit breaker fails to operate.

ONE MAIN SWITCH, by which the current can be cut off from motor control circuit for inspection or in case of defective apparatus.

ONE THIRD RAIL SWITCH, by which current can be cut off from third rail shoes when operating from trolley.

ONE TROLLEY SWITCH, by which the trolley can be cut off from the bus line.

FOUR THIRD RAIL SHOES, which collect current from the third rail.

FOUR SHOE FUSES, which protect the apparatus and car wiring against excessive current.

TWO TROLLEYS, either of which take current from the trolley wire.

One TROLLEY FUSE, which protects the apparatus and car wiring from excessive current.

One BUS LINE, which, together with the bus line jumper, connects all shoes and trolleys of a train together.

TWO BUS LINE FUSES, which protect the bus line against excessive current.

ONE KICKING COIL and one LIGHTNING ARRESTER, which protect the circuits and apparatus against lightning discharges.

8. THE FOUR THIRD RAIL SHOES are connected together through the shoe fuses by a cable, from which a connection is made through the third rail switch on switchboard, through the main switch, main fuse, circuit breaker, contactors, resistances, reverser and motors to the track rails.

9. THE TWO TROLLEYS are connected together by a cable, from which a connection is made through the trolley fuse, then through the kicking coil and trolley switch, located in a box on the roof of the car, to the bus line, from which a connection is made between switch. From the main switch the circuit is the same as from the third rail shoes. A connection is made between the trolley fuse and kicking coil through a lightning arrester, located in the box with the kicking coil on the roof of the car, to ground.

10. THE CONTACTORS, fifteen in number, are enclosed in an iron box, known as the contactor box, located under the car.

The Contactor (Fig. 480) is a switch, the movable portion of which is operated by an electro-magnet receiving line current through the master controller and the train cable. The main contact is made between two heavy copper tips, which are enclosed in an arc chute. A magnetic blowout is provided, having poles extended along two sides of the arc chute, for extinguishing the arc formed in breaking the circuit.

By means of the contactors the motor control is established on individual cars.

11. THE CONTACTOR BOX (Fig. 481) is located beneath the car, about midway between the trucks.

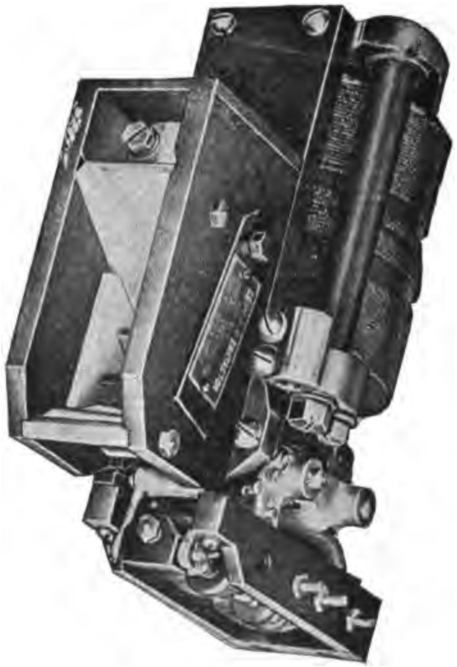


Fig. 480. Contactor.

This box is of iron, lined with asbestos and other insulating materials to prevent short circuits, and is provided with two hinged sheet iron covers. When it is desired to inspect the contactors the sheet iron covers

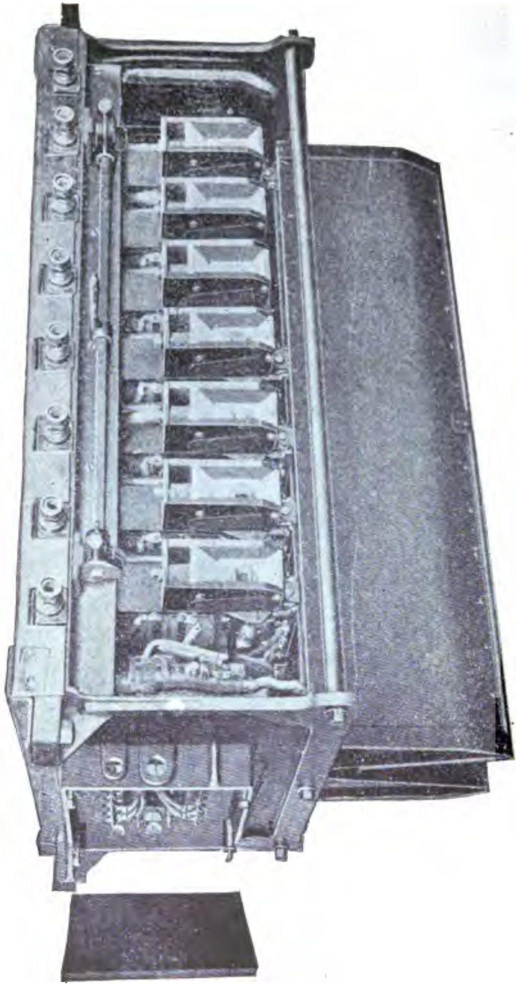


Fig. 481. Contactor Box. Contain 15 Contactors and Potential Relay. Train Cable Connection Box is Mounted on Left End.

can be dropped by releasing the catches which hold them in place.

12. THE REVERSER (Fig. 482) is enclosed in a metal box, and located near the end of the contactor box toward the trailer truck.

The movable part of the reverser is a rocker arm, controlled by two electro-magnets, one for each direction. These magnets are operated by current from the master controller through the main cable, the connections being made so that only one magnet can receive current at a time. Cables from the motor armatures and fields are connected to the fingers of the reverser, and by means of contact pieces mounted on, but insulated from, the rocker arm, proper connections of armatures and fields are established for producing forward and backward movement of the car.

The control connections for the reverser are so arranged that, unless the reverser is at the proper position, current is cut off from the contactors, and consequently the motors on that car receive no current. When the reverser is in the correct position it is electrically locked and cannot be operated while the motors are taking current.

The reverser is always closed, either in the forward or backward position, depending on whether the master controller handle has been moved to the left or to the right.

13. THE RESISTANCE (Fig. 483) is located beneath the car, near the contactors, and is made up of cast iron grids mounted in, and insulated from, an iron frame.

These resistances are used to regulate the flow of current to the motors while the car is accelerating. Cables

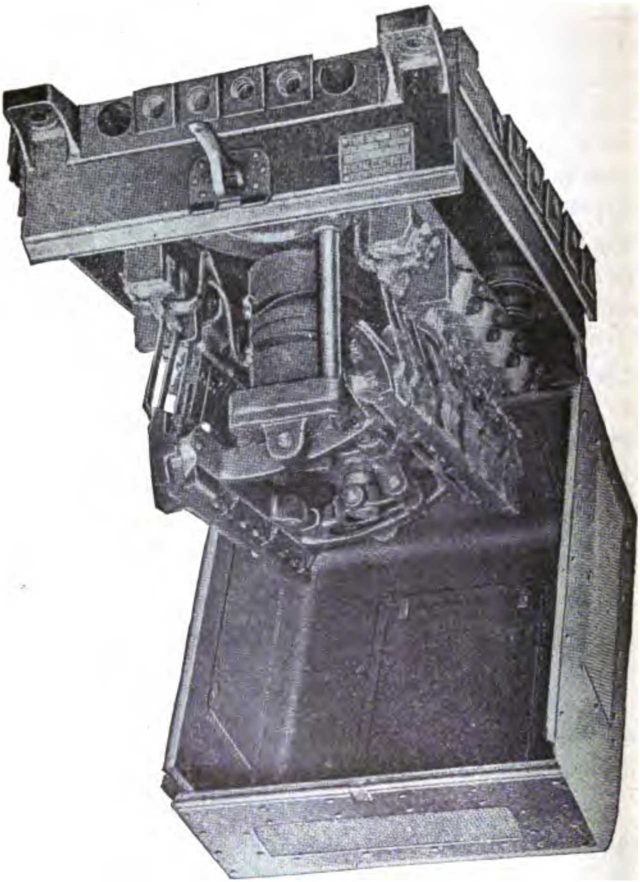


Fig. 482. Reverser.

connect the various resistances to different contactors, so that sections of the resistance may be cut out to increase the speed. Resistances are used only in starting, switching, or moving at low speeds, and are entirely cut out either in the one-half or full speed positions of the master controller handle.

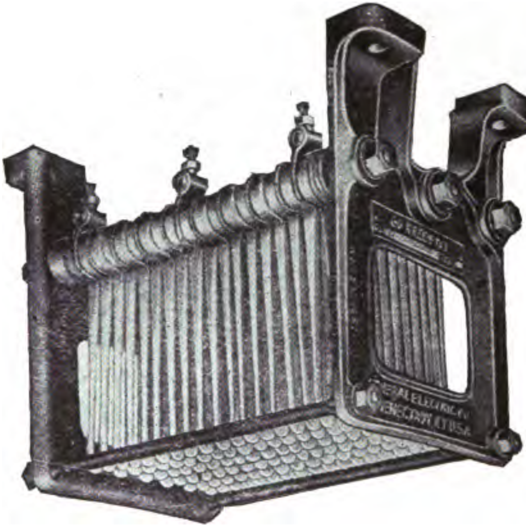


Fig. 483. Motor Control Rheostat.

14. THE CIRCUIT BREAKER (Fig. 484) is enclosed in an iron box, located beneath the car at the end of the contactor box toward the trailer truck.

The circuit breaker is similar in construction to the contactor, but designed to carry and break the full current taken by the car. It is closed and opened by means

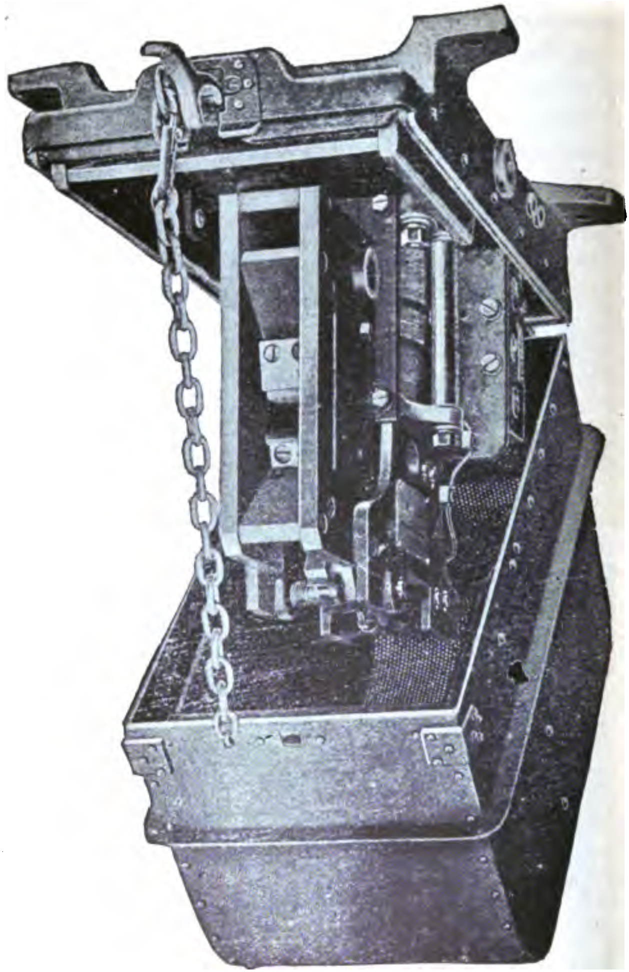


Fig. 484. Circuit Breaker.

of two electro-magnets, acting independently, and operated by current through the train cable and the circuit breaker switch (Fig. 485) which is located in the motorman's cab, above the master controller. The circuit breaker on any car is opened automatically when exces-

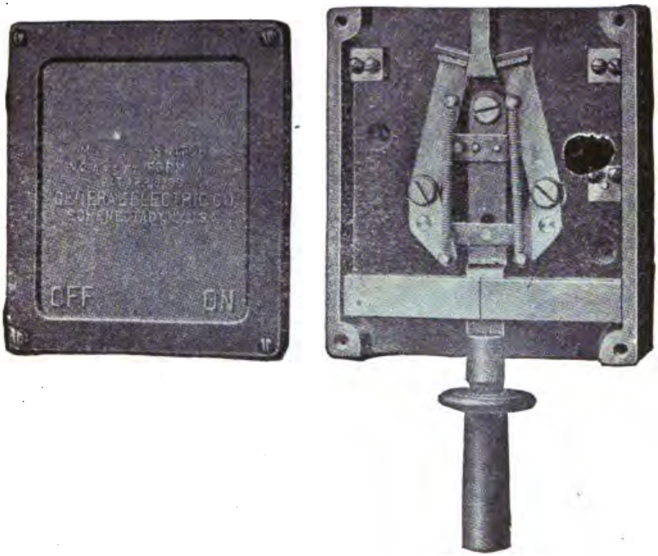


Fig. 485. Circuit Breaker Setting and Tripping Switch.

sive current flows through the motor circuits on that car. As the setting and tripping circuits of all circuit breakers of a train are connected through the train cable, all circuit breakers are closed and opened simultaneously by operating the circuit breaker switch.

The circuit breakers are normally closed when the train is ready for operation.

15. THE MAIN FUSE (Fig. 486) is located beneath the car, at the trailer end, near the main switch.

It is made from a thin copper ribbon and is contained in a box composed of insulating material. Sheet iron poles partially surround the insulation and provide a magnetic blowout for extinguishing the arc formed when the fuse blows.

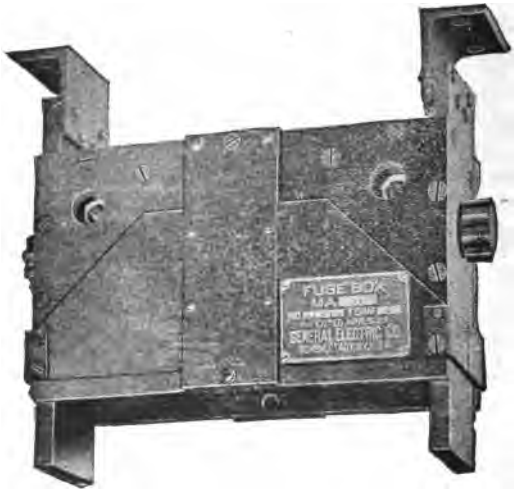


Fig. 486. Main Fuse.

The fuse is held in place by copper clamps, fastened with thumb screws having insulated handles. It may be replaced after opening the main switch, loosening the clamps and removing the ends of the old fuse. Ordinarily the current breaker will open automatically from excess current before the fuse has time to blow.

16. THE MAIN SWITCH (Fig. 487) is located in a box beneath the car. It is a quick-break, knife-blade switch, and is used to cut off the supply of current to

Fig. 487. Main Switch.

the motor circuit from both trolley wire and third rail. This switch is normally closed, BUT SHOULD ALWAYS BE OPEN when examining or working on the motor control apparatus.

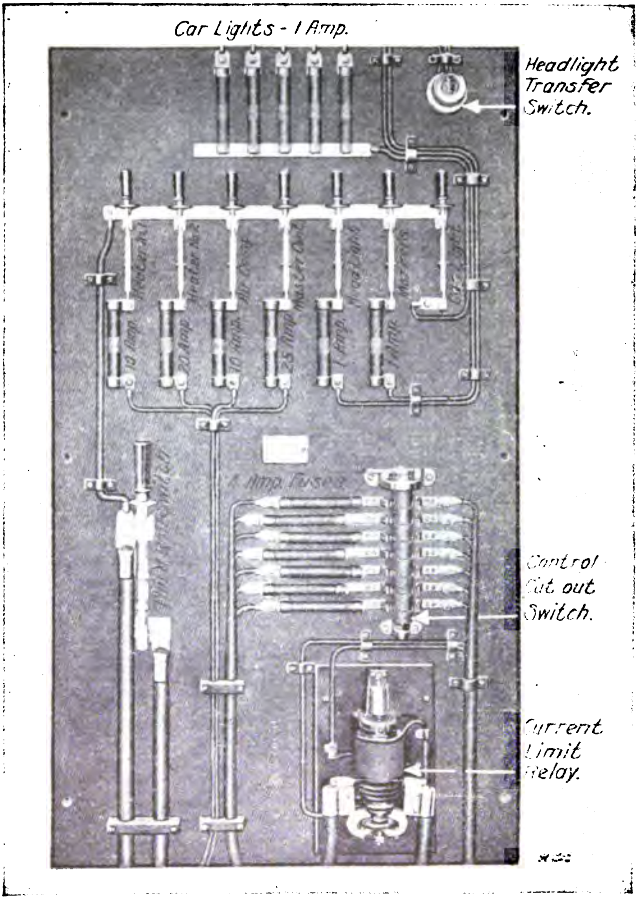


Fig. 489. Switchboard on West Jersey & Seashore Cars.

17. THE THIRD RAIL SWITCH is located on the switchboard (Fig. 489). It is a quick-break, knife-blade switch, and is used to cut off current from the third rail to the motor control circuit and to cut out the third rail shoes when operating from the trolley wire.

This switch is normally closed when the car is taking current from the third rail and open when taking current from the trolley wire. THE SWITCH SHOULD NOT BE OPENED WHILE THE MOTORS ARE TAKING CURRENT, EXCEPT IN AN EMERGENCY.

18. THE TROLLEY SWITCH is located in a box on the car roof. It is a quick-break, knife-blade switch, and is used to cut off the trolley and its fuse from the bus line circuit. This switch is normally closed, BUT SHOULD ALWAYS BE OPEN WHEN WORKING ON THE TROLLEY OR RENEWING A TROLLEY FUSE.

19. THE BUS LINE COUPLER SOCKETS, four in number, are located under the platforms, two at each end of the car.

The coupler socket (Fig. 490) is composed of a body of moulded insulating material, containing a large split plug contact. Supporting feet of malleable iron are secured to this insulating body for attaching to the under side of the car platform. The socket is provided with a hinged lid, having a projection on the inside to hold the jumper plug in place. The cover also excludes dirt and water when the jumper is not inserted. Only one of the two bus line coupler sockets at each platform is in use at a time.

20. THE BUS LINE JUMPER (Fig. 491) is used to connect the bus line coupler sockets on adjacent cars. It consists of a short section of flexible cable, with a plug attached to each end, and completes the bus line between the cars. Only one bus line jumper is required

Fig. 490. Bus Line Coupler Socket.

for connecting between adjacent cars, the additional sockets being provided so that cars may be turned end for end or coupled in any desired relation.

21. THE BUS LINE FUSES, two in number, are located beneath the car, one at each end. They are similar to the main fuse. These fuses are placed in the bus line circuit to protect it against excessive currents.

Fig. 491. Bus Line Jumper.

22. THE BUS LINE JUNCTION BOXES, two in number, are located beneath the car, one at each end.

The box is made of cast iron and contains an insulated board, to which is secured a single stud bolt for holding the cable terminals. This box is provided for connecting the bus line coupler sockets to the bus line cable.

23. THE BUS LINE CONNECTION BOX is located beneath the car, midway between the trucks.

This box is similar to the bus line junction box, and is provided for connecting the third rail and trolley circuits to the bus line cable.

24. THE SHOE FUSE BOXES, four in number, are located on the wooden shoe beams, one on each side of each truck. The box is similar to the main and bus line fuse boxes and contains the shoe fuse.

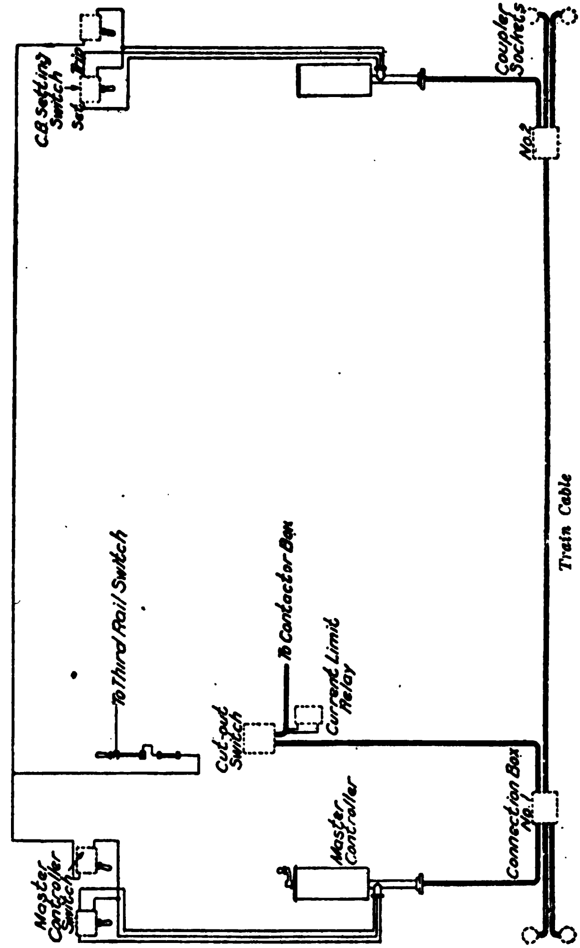
25. THE TROLLEY FUSE BOX is located on the roof of the car. It is similar to the main and bus line fuse boxes and contains the trolley fuse.

MASTER CONTROL.

26. THE MASTER CONTROL CIRCUIT (Fig. 492) is the circuit forming the path for the current from the bus line, through the master controller and the train cable, to the operating coils of the motor control apparatus.

27. THE ESSENTIAL PARTS of the master control of each car comprise the following apparatus:

- TWO MASTER CONTROLLERS, which operate the motor control.
- TWO MASTER CONTROLLER SWITCHES, used to cut off current from their respective master controllers when not in use.
- ONE MASTER CONTROL SWITCH, to cut off current to master controller and circuit breaker switches.
- ONE TRAIN CABLE, which connects the master controllers to the motor control apparatus.
- FOUR TRAIN CABLE COUPLER SOCKETS, to which the train cable jumpers are connected.
- ONE TRAIN CABLE JUMPER, which connects the train cable between cars.
- TWO TRAIN CABLE CONNECTION BOXES, where connection is made to master controllers, coupler sockets and seven-point cut-out switch.



General Arrangement of Master Control Wiring.

Fig. 492.

ONE SET OF RESISTANCE TUBES, which limit the current in the master control circuits.

ONE CURRENT LIMIT RELAY, which limits the rate of acceleration.

ONE POTENTIAL RELAY, which opens the master control circuit when power is cut off from the train.

ONE SEVEN-POINT CUT-OUT SWITCH, to disconnect motor control apparatus from train cable.

TWO CIRCUIT BREAKER SWITCHES, for setting and tripping circuit breakers.

CONTROL FUSES, which protect master control wiring against excessive current.

DESCRIPTION OF MASTER CONTROL APPARATUS.

28. THE MASTER CONTROLLERS, two in number, are located in the motorman's compartments, one at each end of the car.

The master controller (Fig. 493) contains a single movable contact cylinder and stationary fingers, mounted on an insulated support. The controller has a single handle for both forward and reverse direction of train movement. Four points are indicated on the cap plate for forward direction and two for reverse. The first point in either direction is called the "Switching" or "Lap" position; the second, "Full Series." The third point is called the "Parallel Lap" position, and the fourth, "Full Parallel."

The master controller governs the admission of current to the train cable for operating the reverser and contactors.

Fig. 493. Master Controller.

29. THE MASTER CONTROLLER SWITCHES, two in number, are located above each master controller, one at each end of the car.

Fig. 494. Master Controller Switch Without Fuse. Also Negative Control Switch on Locomotive.

The master controller switch (Fig. 494) is a pivoted switch mounted in an iron box and having a projecting handle. It is provided with a magnetic blowout. This switch is used to cut off current from its master controller when the latter is not in use. It also serves as an emergency switch in case of any failure of the master controller.

30. THE MASTER CONTROL SWITCH is located on the switchboard and is of the quick-break, knife-blade type.

The switch is used to cut off current from the master controller and the circuit breaker switches.

The normal position of the switch is open except when the train is being operated from a master controller on that car.

31. THE TRAIN CABLE is located in an iron pipe placed beneath the car.

The train cable is composed of seven conductors, each being covered with a different colored outer braid for identification. These conductors are attached to numbered plugs in the coupler sockets at the ends of the car. Branch cables run from connection boxes in the train cable to the master controllers, seven-point cut-out switch and coupler sockets.

The train cable is used to connect the operating master controller of the motor control apparatus of the car or train. The seven wires are used as follows:

No. 1. (Red) for accelerating or notching up.

No. 2. (White) for series connection of motors.

No. 3. (Green) for parallel connection of motors.

No. 4. (Green and White) for operating reverser one direction.

No. 5. (Yellow) for operating reverser other direction.

No. 6 (Red and Black) for tripping circuit breakers.

No. 7 (Black) for setting circuit breakers.

32. THE TRAIN CABLE COUPLER SOCKETS (Fig. 495), four per car, are attached to the under side of the car platform. These sockets are of malleable iron and contain a body of moulded insulation, into which are set seven bronze split plugs, one being attached to each conductor of the train cable.

Fig. 495. Train Cable Coupler Socket.

Each socket is provided with a hinged cover adapted to hold the jumper plug in place and to prevent the entrance of dirt and moisture when no jumper is inserted.

Fig. 496. Train Cable Jumper.

33. THE TRAIN CABLE JUMPER (Fig. 496) is used for connecting the train cables on adjacent cars. It consists of a short length of seven-conductor cable, with iron heads or plugs attached to the ends, each containing seven insulated contacts, one being secured to each conductor. The jumper heads fit into the coupler sockets on adjoining cars, and connect together their train cables.

34. THE TRAIN CABLE CONNECTION BOXES, two in number, are located beneath the car.

The train cable connection box (Fig. 497) is of iron and is used for making the connections from the master controller, circuit breaker, coupler sockets and cut-out switch to the train cable. Seven screw studs, which are held in an insulating board, are used for securing the terminals attached to the ends of the entering cables.

Conductors provided with the same colored covering are connected together, except at one connection box on each car, where Nos. 4 and 5, which operate the reverser, are crossed in order to obtain a direction of car movement to agree with the position of controller handle in either controller.

35. THE RESISTANCE TUBES are located in the contactor box, and consist of twelve tubes wound with resistance wire. They are used to regulate the current in the operating coils of the contactors.

36. THE CURRENT LIMIT RELAY (Fig. 498) is located on the switchboard. It consists of an electromagnet provided with two coils. The master control circuit passes through the upper coil and the main circuit for motor No. 1 through the lower coil. The master control circuit coil lifts the plunger for each step during acceleration and interrupts the contactor pick-up circuit.

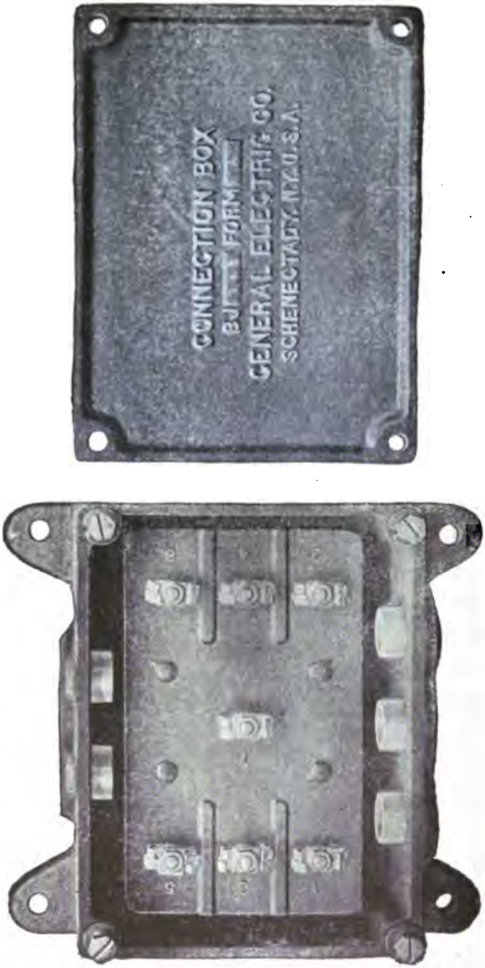


Fig. 497. Train Cable Connection Box.

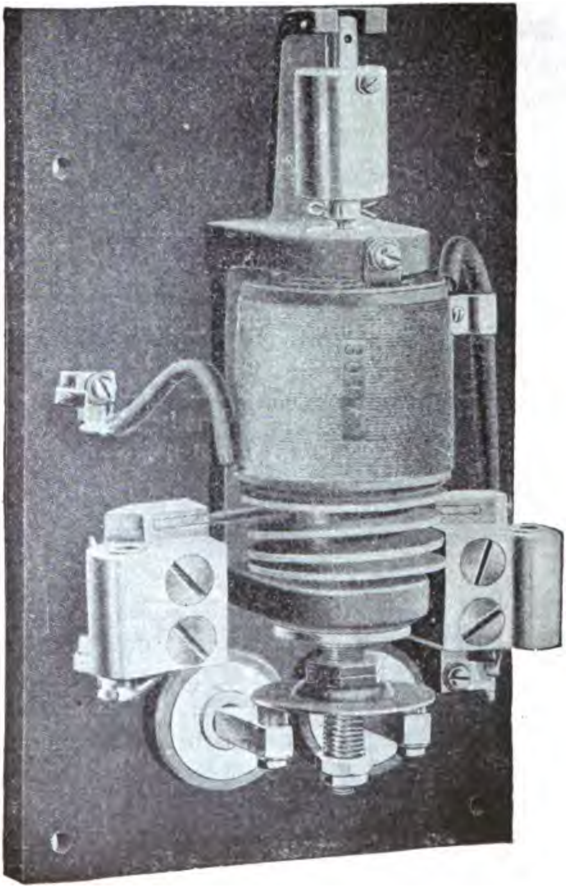


Fig. 498. Current Limit Relay.

If the current flowing through the main circuit coil is more than a certain amount the plunger is held in its upper position and cannot drop until the motor current has fallen to the desired amount.

The relay is provided for the purpose of producing an automatic control during acceleration.

37. THE POTENTIAL RELAY (Fig. 499) is mounted in the contactor box. It is similar to the current relay in construction, but is used for a different purpose. The relay has a coil which is connected between a point in the motor circuit, ahead of the first motor, and ground. If for any reason the motor current is interrupted on a car, this relay will open the master control circuit to the contactors on that car, causing them, in turn, to open. When current is restored to the car, the relay will again pick up and complete the master control circuit. The contactors will then pick up in regular succession, the same as if the motorman had shut off power and immediately turned the master controller handle on again.

38. THE CONTROL CUT-OUT SWITCH is mounted upon the switchboard. It consists of copper contacts, mounted on an insulated drum, and two sets of fingers fastened to the switchboard. It is provided for the purpose of disconnecting the master control circuit, to the contactors reverser and circuit breaker on the car, from the train cable.

39. THE CIRCUIT BREAKER SWITCHES, two in number, are located one above each master controller.

The circuit breaker switch (Fig. 485) is mounted in a cast iron box and consists of a pivoted blade, with a handle extending below the box.

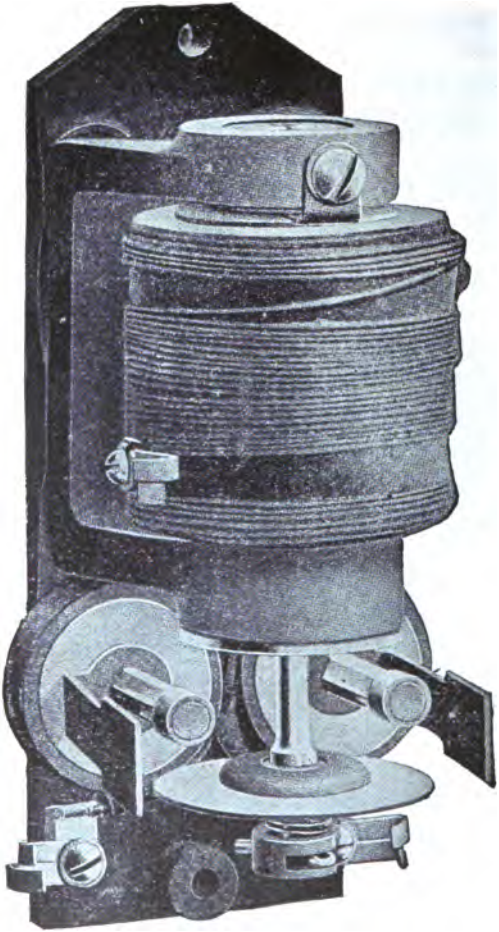


Fig. 499. Potential Relay.

The handle, when turned to the right, makes connection through a contact with the setting coils of the circuit breakers; when turned to the left, with the tripping coils of the circuit breakers. These positions are indicated by the words "On" and "Off" on the face of the box.

The normal position of the handle is vertical, and is held in this position by two springs.

40. CONTROL FUSES are mounted on the switchboard beside the control cut-out switch. A fuse is placed in each of the seven control circuits between the train cable and the cut-out switch.

41. THE SWITCHBOARD (Fig. 489) is located in the vestibule at the trailer end of the car, and has mounted upon it the following apparatus:

The THIRD RAIL SWITCH. (Paragraph No. 17.)

The SEVEN-POINT CUT-OUT SWITCH and FUSES. (Paragraph Nos. 38 and 40.)

The CURRENT LIMIT RELAY. (Paragraph No. 36.)

The MASTER CONTROL SWITCH AND FUSE. (Paragraph No. 30.)

SWITCHES AND FUSES FOR AIR COMPRESSOR, LIGHTS AND HEATERS.

42. THE EMERGENCY AIR BRAKE ATTACHMENT for master controller (Fig. 493) consists of a main valve outside of the controller (Fig. 500), and a small pilot valve (Fig. 501) within it. The main valve

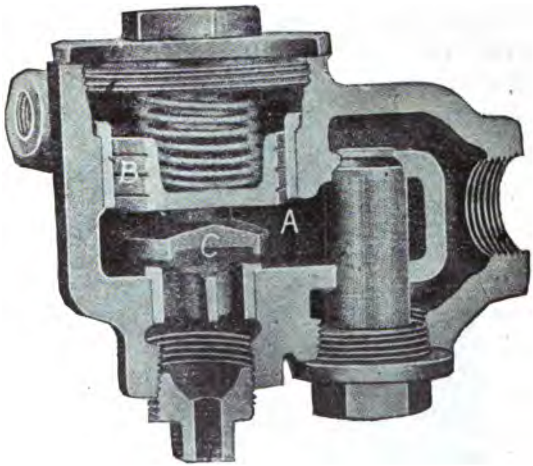


Fig. 500. Main Valve. Emergency Air Brake Attachment.

contains a chamber "A," divided into two parts by a piston "B" connected to a valve "C," exhausting to atmosphere. The lower part of the chamber "A" connects directly to the brake pipe. The upper part of "A" connects to the pilot valve through "F" and pressure in both parts is equalized by a small hole in the piston "B." When the pilot valve is opened, pressure in the upper part of the main valve is reduced, and the piston lifts, allowing the brake pipe to exhaust through a hole in the

bottom of the main valve to atmosphere. The pilot valve is opened by a loose collar on the cylinder shaft in the controller, which presses against the stem of the valve when the controller handle is at the "Off" position and the button released.

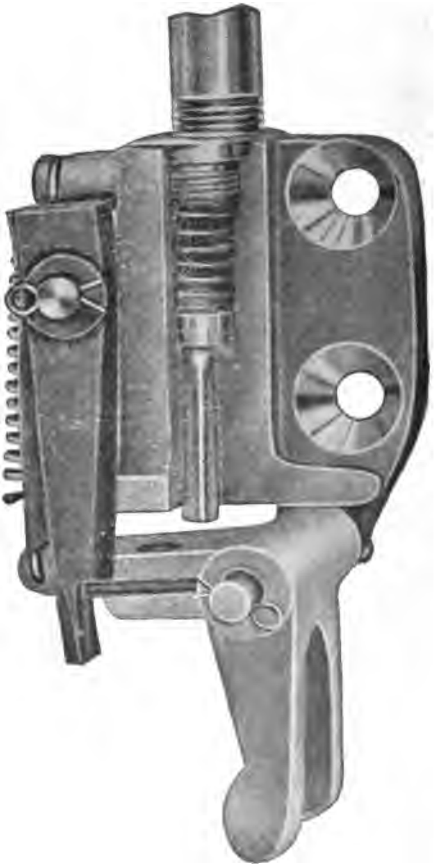


Fig. 501. Pilot Valve Emergency Air Brake Attachment.

TRAIN OPERATION.

43. GENERAL—The apparatus will be inspected and the train put in condition for operation by the inspectors; but the motorman will be held responsible for the operation of the apparatus while in his charge, and he should, therefore, familiarize himself with the location, use and operation of all apparatus on the cars, and should carefully follow the instructions below:

44. PREPARATIONS FOR STARTING—When the train is turned over to motorman, he should:

FIRST—Pass along the outside of train, carefully examining bus line and train cable jumpers between cars, to assure himself that all connections are properly made and that main switches are closed.

SECOND—Pass through the train, closing air compressor and third rail switches in each car, and opening master control switches in all cars except head car or car from which train is to be operated.

THIRD—Pass along outside of train again and satisfy himself that the air compressors are working properly.

FOURTH—Take position in the motorman's compartment at forward end of train and note the brake pipe pressure, which should be seventy pounds, close master controller switch. Thc circuit breakers should then

be set by moving the circuit breaker switch, over the master controller, to the "On" position—holding it there about one second to allow time for all circuit breakers to set.

FIFTH—Test the brakes as required by "Air Brake Instructions," making, upon request of the trainmen or inspectors, a full service application (twenty-pound reduction of pressure), holding them on until the trainmen or inspectors have examined the brakes on each car.

If the brakes are found in proper condition, trainmen or inspectors shall signal the motorman, from the rear of the train, who will then release the brakes.

The test is not complete until the trainmen or inspectors have re-examined the brakes, which should be done as quickly as possible, to see that they have released properly, after which the inspectors must report their condition to the motorman.

The train is now ready to be started.

45. TO START—Press down the button in the controller handle, insert the handle key and give it a quarter turn. The button must now be held down to prevent the pilot valve in the controller from operating and applying the brakes. Move the controller handle to the left as far as it will go, holding it there against the spring, which tends to return it to the "Off" position. The motor control will then notch up to full speed position by the automatic progression of the contactors, in successive steps, under the control of the current limit relay. In this

position it is not necessary to hold the button down to prevent application of the brakes.

46. COASTING—Hold the button down and move controller handle to "Off" position. In this position power will be shut off and the train may coast free.

47. SERVICE STOP—The service stop will be made by the air brake valve in accordance with the "Air Brake Instructions."

48. EMERGENCY STOP—The emergency stop may be made by releasing the controller handle, which will then return to the "Off" position, shutting off the power and applying the brakes.

49. TO START SLOWLY—Move the controller handle to the left to first point. In this position both motors on each car are connected in series with all resistance in circuit and the motor control will not "notch up" to higher speed.

50. TO INCREASE SPEED SLIGHTLY—Move the controller handle to the second point and quickly return it to first point. This operation results in the cutting out of one step of resistance, and may be repeated until all the resistance is cut out, thus slowly notching up under the control of the motorman and not automatically.

If the controller handle is left on the second point for a sufficient length of time, all resistance will be automatically cut out in successive steps, under the control of the current limit relay, until full series or half speed is reached.

51. RUNNING POSITIONS—The second and fourth notches are running positions, and the train should not be operated for more than a few minutes at a time with the controller handle on intermediate notches.

52. TO REVERSE—Move the controller handle to the right to the first point. The reverser will change the direction of train movement, and the motors will be connected in series with all resistance in circuit.

It is not possible to run above half speed in the reverse direction, and if higher speed is required, it can only be obtained by operating the master controller at the other end of the car or train.

TRAIN FAILURE.

53. A TRAIN FAILURE, that is, a failure of a train of one or more cars to move or to attain full speed, when the directions for train operation have been followed, may be due to one or more of the following causes:

FIRST—FAILURE OF POWER.

SECOND—DEFECT IN MASTER CONTROL CIRCUIT.

(a) Master control fuse blown or imperfect.
(b) Grounded train cable.
(c) Poor contact in master controller.
(d) Loose train cable jumper.

THIRD—DEFECT IN MOTOR CONTROL CIRCUIT.

(a) Circuit breakers open.
(b) Bus fuses blown.
(c) Loose or disconnected bus jumper.
(d) Main fuse blown.
(e) Shoe or trolley fuses blown.

FOURTH—FAILURE OF AIR BRAKES TO RELEASE.

FAILURE OF POWER.

54. A FAILURE OF POWER can be detected by closing the lighting switches; if lights burn, power is on.

DEFECT IN MASTER CONTROL CIRCUIT.

55. TO DETERMINE IF MASTER CONTROL CIRCUIT IS OPEN turn master controller handle to the first notch and open the master controller switch. The noise of slight arcing indicates that the master control circuit is closed and that the trouble is elsewhere. No arcing shows that the master control circuit is open and indicates that fuse is blown or imperfect. A black or charred spot in the center of the label, called a "Telltale," indicates that the fuse is blown and should be replaced. A fuse which shows no indication of being blown should be tested to detect faulty construction by removing a fuse from a lighting circuit and inserting the fuse to be tested. The lights burning indicate that the fuse is good, and it can then be replaced.

56. TO DETERMINE IF TRAIN CABLE IS GROUNDED, operate the master controller. If the master controller fuse blows, it indicates that one or more wires of the train cable are in contact with the ground, and the cable is said to be "grounded."

To locate a ground in the train cable, disconnect train cable on operating car from rest of train by removing train cable jumper from its socket on second car. If the fuse now blows, when the controller handle is operated, it indicates that the ground is either in the operating car or its train cable jumper.

To determine whether ground is in train cable or jumper, remove the jumper. If the fuse blows when the con-

troller is operated, the ground is in the car. If it does not blow, the ground is in the jumper, and a new one should be inserted. If the fuse does not blow when the jumper is disconnected from the second car, the jumper should be replaced, and the one between the second and third cars disconnected from its socket on the third car, and so on until the fault is located.

If the fault is found to be caused by a defective jumper, and if the train is not provided with an extra jumper, the jumper between the two last cars of the train should be taken to replace the defective one.

If the fault is found to be on the car and not in the jumpers, the seven-point control cut-out switch on that car should be turned to the "Off" position, and the test repeated. If the fuse still blows when the handle is operated, the fault is in the train cable. If the fuse does not blow, the ground is between the cut-out switch and the contactors, reverser and circuit breaker. If this is the case, the cut-out switch on the defective car should remain in the "Off" position, thus cutting out the fault as well as rendering the car inoperative, but in no way interfering with the train cable, and permitting the operation of other cars in the train, through the train cable in the usual manner.

If opening the cut-out switch does not remove the fault, that is, if the fault is in the train cable and the defective car is near the rear end, the train should be operated from the front car as usual, the defective car and those following being cut out by removing both train cable jumpers on that car; if at or near the head of the train, the train should be run from the following car, all cars ahead being cut out.

57. TO DETECT POOR CONTACT IN MASTER CONTROLLER, open the master controller switch, remove the cover from the controller and turn the handle slowly, noting if each finger makes good contact with the drum. If any contact is poor and cannot readily be re-adjusted by the motorman, he should run the train from the next car.

58. TO DETECT LOOSE TRAIN CABLE JUMPER, the trainmen should note if the contactors on each car are working while the train is accelerating. If there is a loose train cable jumper, all cars ahead of the jumper will operate; others will not. The motorman should be immediately informed if any car is not operating.

DEFECT IN MOTOR CONTROL CIRCUIT.

59. IF ONE OR MORE CIRCUIT BREAKERS OF A TRAIN BLOW when starting or running, return the controller handle to the "off" position and move the handle of the circuit breaker switch to the "on" position. If the circuit breakers again blow when the controller handle is operated, the brakes should be examined to see if they have released.

If the circuit breaker on any car repeatedly blows, the motorman should make an examination to see that it is properly adjusted. If the trouble is not with the circuit breaker, the car should be cut out by opening the seven-point cut-out switch on the switchboard and the main switch beneath the car.

Blowing of the circuit breaker is accompanied by a loud report.

60. AN OPEN CIRCUIT IN BUS LINE may be detected when the train is at a crossover and current cannot be obtained on operating car, although other cars of the train have current. This indicates that the bus line fuse or fuses are blown, or that a bus line jumper is loose or disconnected between the operating and adjacent cars.

The motorman should inspect the bus line jumpers, and if the trouble cannot be quickly remedied, he should go back to the first car having current and move the train through the crossover. The motorman should then return to the first car and proceed in the usual manner.

61. WHEN THE MAIN FUSE IS BLOWN, the motors will not operate, although the contactors may be in working order and the circuit breaker closed. This should occur very seldom, as it can only be caused by short circuit or grounding in the motors or motor circuits, which are usually protected by the quicker acting circuit breaker. This fuse should not be replaced on the road except to avoid serious delay to the service, as in the case of single cars. BEFORE RENEWING MAIN FUSE, OPEN THE MAIN SWITCH.

62. A SHOE FUSE MAY BLOW from short circuit, grounding of the car wiring on some part of the car or truck, or may be caused by a contact shoe on the car or train grounding, due either to being broken or from fouling or picking up something along the line. If it is necessary to replace a shoe fuse on the road so as to prevent delay to service, the motorman should open the third rail switch on the switchboard and insert the wooden paddles, provided for that purpose, between all shoes on that car that are in contact with the third rail.

63. A TROLLEY FUSE MAY BLOW from short circuit or grounding of the car wiring on the car or

truck, or because it has been overloaded by running in a train with other trolleys down and taking current for the whole train through the one fuse. If this latter has been the cause, the fuse should be replaced on the road if it is required to prevent delay to service. Before replacing the fuse, pull down both trolleys and open the trolley switch.

GENERAL DIRECTIONS.

64. IN CASE OF FIRE beneath any car in the train, the motorman should open all circuit breakers by moving the circuit breaker switch to "OFF" position. If this fails, he should open the main switch beneath the car and the seven-point cut-out switch on the switchboard.

65. IF SMOKE OR FIRE IS OBSERVED by the trainmen in any of the lighting or heater circuits within the car, they should IMMEDIATELY open the switch controlling the circuit, and extinguish the fire with SAND. NEVER USE WATER to extinguish a fire when power is "ON," as water is liable to increase the danger by causing further short circuits.

66. UNUSUAL NOISES in train movement should at once be located. To avoid delay the conductor or brakeman should stand beside the train while it is moved slowly. If noise is caused by brake rigging, the same should be tied up; if the noise is located within the motors, and the schedule permits it, the motors should be cut out by opening the seven-point cut-out switch on that car.

67. A BROKEN THIRD RAIL SHOE or shoe support should be broken completely off or tied up, whichever, in the judgment of the motorman, will cause the least delay. In either case, open the third rail switch on switchboard and insert wooden paddles between third rail and all contact shoes on the car. To break off remainder of shoe, use some tool with a wooden handle, as a hammer or ax. NEVER USE A CROWBAR OR COUPLER PIN FOR THIS PURPOSE.

68. TO STOP TRAIN WHEN AIR BRAKES FAIL, turn controller to first notch in reverse position. THIS SHOULD ONLY BE DONE IN CASE OF EMERGENCY AND TO AVOID ACCIDENTS.

69. CAUTION—Employes should exercise extreme care while working about or on car wiring. The switch controlling the circuit on which work is being done should always be open.

70. MOTORMEN MUST REPORT at the end of each trip, on the regular form provided for the purpose, all detentions and reasons for such detentions and any defects in electrical, air and signal apparatus.

The New York Central is now operating a portion of the 289 miles of track which will soon be entirely operated by electricity.

Their equipment which is now all in use consists of 125 motor cars each containing 400 H. P. of electric motors and 35 locomotives each of 220 H. P. with large overload capacity. Each locomotive will develop 2500 H. P. before blowing fuses, and can sustain that power for several minutes.

Recently a train of 9 Pullmans went dead on a 0.5% grade in the tunnel, on account of engine trouble. One of the electric locomotives coming up behind with 7 coaches, at once coupled on and started the whole combination of itself, a dead locomotive and 16 cars, the whole weighing about 1000 tons. It drew the whole up a 1% grade about half a mile long at good speed and landed them at the Mott Haven yard.

The motor car trains make a maximum speed of 52 miles per hour.

The locomotive trains make a maximum of about 66 miles an hour with regular trains.

SUBURBAN MOTOR CARS.

A.—General.

1. Sprague-General Electric Type "M" control system, as supplied to the Suburban Motor Cars of the New York Central & Hudson River Railroad Company, comprises two distinct sets of controlling apparatus, namely, the main or motor control and the master control.

2. Each motor car is equipped with a set of motor control apparatus which serves to carry current from the third rail through the motors to ground, forming different combinations of motors and cutting out resistances in starting that particular car. Each motor circuit is local, being confined to its respective car.

3. Every motor car in the train is equipped with master control apparatus, the office of which is to operate the motor control. An important feature of the master control is the train cable, comprising seven conductors running the entire length of the train with suitable couplers between cars. On every motor car a connection is made from this cable to the motor control apparatus on that car. At every cab connection is made from the train cable to a master controller. Consequently, any master controller on a train can energize the entire train cable and operate all the motor control apparatus connected to it.

B.—Motor Control.

4. The motor control on each car consists of the following apparatus:

A set of Contactors mounted in a box.
A Reverser.
A set of Rheostats.
A Circuit Breaker
A Main Fuse.
A Main Switch.

5. In addition to these pieces of apparatus there are four third rail shoes with the necessary main cables connecting them to the control apparatus on the same car. There is also a main cable extending the whole of the train and provided with couplers between cars which connects the third rail shoes throughout the train together. This cable is termed the bus line.

6. From the third rail shoes the main circuit is carried to the main switch on the panel board and from there through the main fuse and circuit breaker to the contactors.

7. THE CONTACTOR (Fig. 480) is a switch, the movable portion of which is operated by an electro-magnet which receives line current from the master controller through the train cable. Where the main contact is made two heavy copper tips are provided. These two contact tips are inclosed in an arc chute, and a powerful magnetic blowout is provided having poles extending along two sides of the arc chute for promptly extinguishing the arc formed in breaking the circuit.

8. A CONTACTOR BOX (Fig. 481) is provided for holding the set of fifteen contactors. This box is of iron, heavily lined with asbestos and other insulating materials for preventing short circuiting. This box is provided with two sheet-iron covers, which can be readily dropped down by releasing suitable catches when it is desired to inspect the contactors. These contactors are supported in the box by means of insulated bolts.

9. THE REVERSER (Fig. 482) is a multiple switch, the movable part of which is a rocker arm operated by two electro-magnets, one being used for each direction. These coils are energized by current from the master controller circuit, and the connections are such that only one coil can receive current at one time. Wires from the motor armatures and fields are connected to the fingers of the reverser, and, by means of contact pieces on the rocker arm insulation, the proper connections of armatures and fields are established for producing forward and backward movement of the car. The reverser is installed in a metal box provided with a hinged cover, held in place by a swing latch.

10. THE MOTOR CONTROL RHEOSTAT (Fig. 483) is made up with a number of cast-iron grids mounted in, and insulated from, an iron frame. These rheostats are used to regulate the supply of current to the motors while the car is accelerating. Cables connect the various rheostats to different contactors, so that the latter may cut out sections of resistance as required.

11. THE CIRCUIT BREAKER (Fig. 484) is similar in construction to a contactor, but designed to carry and break the full current taken by a car. It is closed by means of an electro-magnet which is energized by a setting switch located in the motorman's cab. The circuit

breaker is tripped automatically when excessive motor current flows through its series tripping coil. The motorman may also trip the circuit breaker by moving the combined setting and tripping switch handle to "off" or trip position.

12. THE MAIN FUSE (Fig. 486) is a thin copper ribbon contained in a box composed of insulating material. Sheet-iron pole pieces partially surround the insulation and provide a magnetic blowout for expelling the arc formed when the fuse melts. The fuse will ordinarily not melt and open the circuit, as the time required for this is greater than that taken by the circuit breaker to trip. A continued excessive current will, however, melt the fuse.

13. THE MAIN SWITCH is a knife blade quick break switch, located on the panel, and is used to cut off the supply of current through the main fuse, circuit breaker, contactors and motors. This switch should not be opened while the motors are taking current, except in an emergency. It should, however, always be opened before the main fuse, circuit breaker or contactors are examined. Fig. 502.

14. THE BUS LINE COUPLER SOCKET (Fig. 490) composed of a body of molded insulating material containing a large split plug contact. Supporting feet of malleable iron are secured to this insulating body for attaching to the under side of the car platform. A hinged lid at the front of the socket is also provided, having the two functions of holding the coupler plug in place and excluding dirt and water when the jumper is not inserted.

15. THE BUS LINE COUPLER OR JUMPER (Fig. 491) consists of a short section of flexible insulated

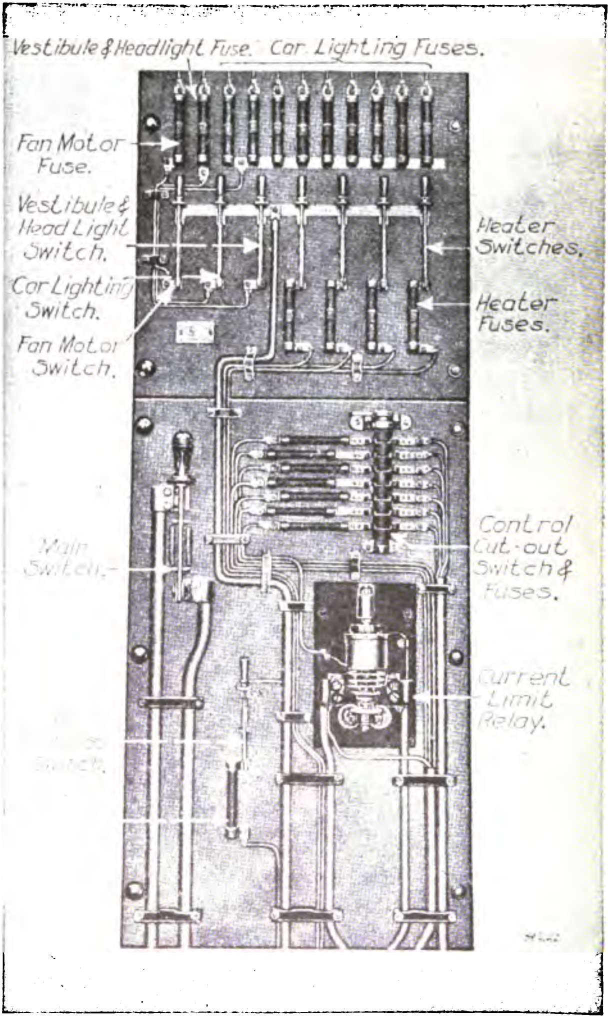


Fig. 502. Switchboard—New York Central Equipment.

cable with a plug attached to each end. But one jumper is required for connection between two adjacent cars, the additional sockets being provided so that cars may be turned end for end, or coupled, in any desired relation.

16. THE BUS LINE FUSE is identical with the main fuse. Two of these are provided, as shown on diagram, for protecting the bus line.

17. THE BUS LINE JUNCTION BOX is provided for connecting the ends of the bus line cable. The box is composed of cast iron and contains an insulating board, to which is secured a single stud bolt for holding the cable terminals.

18. THE SHOE FUSE BOX is very similar to the main and bus line fuse boxes, but is adapted for attachment to the wooden third rail shoe beam.

C.—Master Control.

19. THE MASTER CONTROL APPARATUS comprises the following for each car:

Two Master Controllers.
Two Master Controller Switches.
Train Cable.
Four Train Cable Coupler Sockets.
One Train Cable Coupler or Jumper.
Two Train Cable Connection Boxes.
Current Limit Relay.
One Potential Relay.
One Cutout Switch.
Two Circuit Breaker Setting and Tripping Switches.
Control Fuses.

20. THE MASTER CONTROLLER (Fig. 493) contains a single movable contact cylinder and stationary fingers mounted on an insulated support. The function of the master controller is to supply current at the will of the motorman to the train cable for operating the reverser and contactors. The controller has a single handle for both forward and reverse direction of train movement. Four points are indicated on the cap plate for forward direction and two for reverse. The first point in either direction is called the "switching" or "lap" position, the second "full series." The third point forward is called the "parallel lap" position and the fourth the "full parallel."

21. THE MASTER CONTROLLER SWITCH (Fig. 503) is located over the master controller and is used for admitting current to the master controller at the operating end of the train. A suitable enclosed fuse is located within the switch box to protect the master control circuit.

22. THE TRAIN CABLE is composed of seven conductors, each being covered with different colored braiding for identification. These conductors are attached to numbered plugs in the coupler sockets at the ends of the car and branch wires extend to the master controllers.

These seven wires are used as follows:

No. 1. For accelerating or notching up.
No. 2. For series connection of motors.
No. 3. For parallel connection of motors.
No. 4. For operating reverser one direction.
No. 5. For operating reverser other direction.
No. 6. Tripping circuit breakers.
No. 7. Setting circuit breakers.

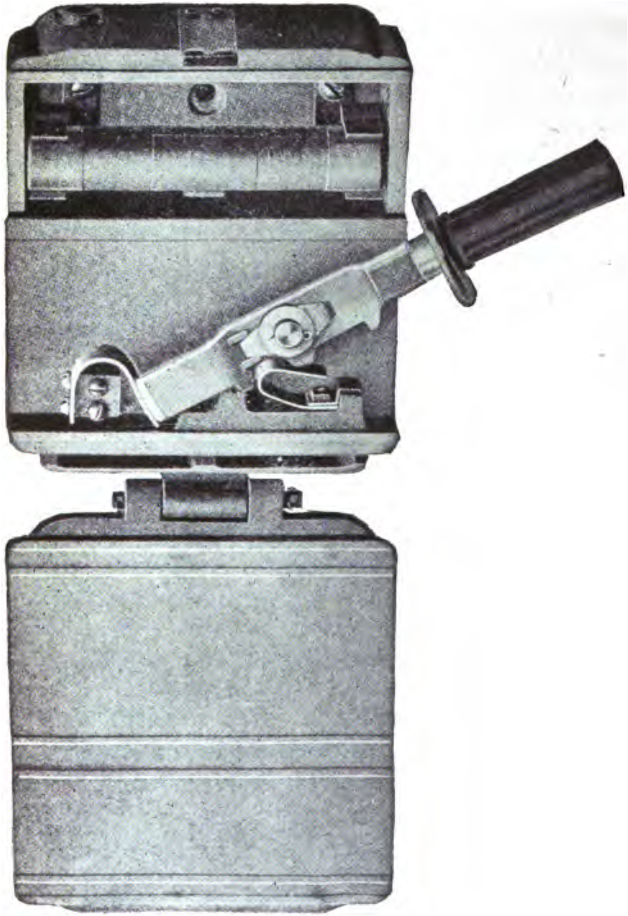


Fig. 503. Master Controller Switch; Pump Switch; also Main Sander Switch on Locomotive.

In order to secure the proper protection from injury the train cable is carried in iron conduit.

23. THE TRAIN CABLE COUPLER SOCKET (Fig. 495) is attached to the under side of the car platform. This socket is of malleable iron and contains a molded insulation body into which are set seven bronze split plugs, one being attached to each conductor of the train cable. The socket is provided with a hinged cover, adapted to hold the jumper plug in place and to prevent the entrance of dirt and moisture when no jumper is inserted.

24. THE TRAIN CABLE COUPLER, OR JUMPER (Fig. 496) is used for connecting the train cables on adjacent cars together. It consists of a short length of seven-conductor cable, with heads or plugs attached to the two ends, each containing seven insulated contacts, one being secured to each conductor. The jumper heads fit into the coupler sockets on two adjoining cars, and connect their train cables together.

25. THE TRAIN CABLE CONNECTION BOX (Fig. 497) is used for making the connections from master controller, circuit breaker setting and tripping switches and coupler sockets to the train cable. Seven screw studs, which are held in an insulating board, are used for securing the terminals attached to the ends of the entering cables. Conductors provided with the same colored covering are connected together, except at one connection box on each car, where the two wires Nos. 4 and 5, which operate the reversers, are crossed in order to obtain the direction of car movement to agree with position of controller handle in either controller.

26. THE CURRENT LIMIT RELAY (Fig. 498) is provided for the purpose of producing an automatic

operation of the control. The control circuit passes through the upper coil and the main circuit for one motor through the lower coil. The control circuit coil lifts the plunger for each step during acceleration and interrupts the contactor pick-up circuit. If the current flowing through the main circuit coil is more than a certain amount the plunger is held in its upper position and cannot drop until the motor current has fallen to the desired amount. This relay is mounted on the panel board.

27. THE POTENTIAL RELAY (Fig. 499) is somewhat similar to the current limit relay in construction, although it is used for a different purpose. This relay has a coil which is connected between the motor circuit, before reaching the first motor, and ground. If for any reason the motor current is interrupted on a car, this relay will open the control circuit to the contactors on that car and the contactors will drop open. When current is restored to the car the relay will again pick up and complete the control circuit. The contactors will then pick up in regular succession the same as if the motorman had shut off power and immediately turned the master controller handle on again. This relay is mounted in the contactor box.

28. THE CONTROL CUT-OUT SWITCH (Fig. 502) is provided for the purpose of disconnecting the control circuits of the contactors, reverser and circuit breakers on a particular car from the train cable. This switch is located on the panel board at one end of the car where it can be easily reached.

29. CIRCUIT BREAKER SETTING AND TRIPPING SWITCH (Fig. 485). This switch is provided with a single handle having springs to return it to a

mid-position. Moving the handle in one direction makes connection from the master controller switch through the train cable to the various setting coils of the circuit breakers. Moving the handle in an opposite direction completes a circuit from the master controller switch through train cable to the tripping coils on the various circuit breakers throughout the train. This switch is conveniently located above the master controller, and the two operating positions for the handle are indicated by "on" for setting and "off" for tripping.

30. CONTROL FUSES (Fig. 502) are placed in the circuits between cut-out switches and operating coils of contactors, reverser and circuit breaker on each car for providing suitable protection. These fuses are located on the panel switchboard in an accessible place.

31. EMERGENCY AIR BRAKE ATTACHMENT.—The emergency air-brake attachment for master controller (Fig. 500) consists of a main valve outside of the controller and a small pilot valve (Fig. 501) within it. The main valve contains a chamber "A," divided into two parts by piston "B," connected to a valve "C" exhausting to atmosphere. The lower part of the chamber "A" connects to the pilot valve through "F," and pressure in both parts is equalized by a small hole in the piston "B." When the pilot valve is opened pressure in upper part of main valve is reduced and the piston lifts, allowing the train line to exhaust through a hole in the bottom of the valve to atmosphere. The pilot valve is opened by a loose collar on the cylinder shaft in the controller, which presses against the stem of the valve when controller handle is at the "off" position and the button released.

D.—Train Operation.

32. Before attempting to start a train the motorman should close the air-compressor switches located on the panel boards of the various cars and wait until the train line and reservoir are properly charged, following the air-brake instructions in regard to testing brakes.

33. He should then see that all main switches are closed and all master controller switches open, with the exception of the one near the controller, which he is to operate. He should also move the circuit-breaker switch to its "on" position, allowing about a second for the circuit breakers throughout the train to close.

34. To start the train press down the button in the controller handle, insert the handle key and give it a quarter turn. The knob in the top of the handle must now be held down to prevent the pilot valve in the controller from operating and applying the brakes.

35. If it is desired to have the control notch up to the maximum speed position, the operating handle should be moved at once to the left as far as it will go and held there against the spring pressure tending to return it to the "off" position. While in any running position the knob in the handle need not be held down, as the air brakes will not be applied automatically unless the controller handle is at its "off" position and the knob released.

36. When the controller is at the full "on" position control current passes from the master controller switch through the master controller to the train cable and thence to the various cars of the train. If the reversers are not thrown to the position corresponding with the move-

ment of the controller handle current will first pass through the proper operating coil of the reversers to ground. After the reversers have reached the correct position interlocking contacts on them cut off circuit to ground and establish one through four contactor coils. Simultaneously current passes from the master controller through another train wire (called the series retaining or No. 2 wire) to a fifth contactor coil, and this contactor, in conjunction with the other four, produce the first or switching point. At the same time a third wire (the notching or No. 1 wire) is energized and the circuit is established through the current limit relays pick-up coil and the resistance contactors, so that the progressive steps are started. Each of these resistance contactors in picking up prepares the control circuit, by means of interlocking switches located on the bottom of contactors, for the next step; it also cuts out the contactor from the "notching" circuit and connects it in the "retaining" circuit. The current limit relay, in lifting, opens the notching circuit and thereby prevents the contactor for the succeeding step from lifting at once. When the current in the motor circuit coil has reached a sufficient amount to prevent the current limit relay from dropping, this notching circuit is not immediately completed and the progression is temporarily arrested. When the relay again drops another contactor is closed, and the same action is repeated until the last or full parallel is reached.

37. The main or motor current flows from the third rail shoes to the main switch, through the circuit breaker and main fuse to the contactors, then through the reverser and No. 1 motor to a set of rheostats, then through another set of rheostats and No. 2 motor to ground. The motors are now in "series" with all resistance in

circuit and the car starts slowly. On succeeding steps until the full series position is reached, the rheostats are cut out in five more steps by the automatic operation of the contactors. After the full series position has been reached a "Bridge" connection is established by the contactors, and the motors are then connected in parallel with rheostats connected in series with each. The same automatic "notching up" of the contactors continues, the controller handle being in the fourth forward position, until all the resistance is cut out of circuit by means of the contactors, and the motors are in full parallel.

38. If it is desired to operate the train at low speed, as in switching, the master controller handle should be moved to the left for forward direction, to the first point only. On this point the full resistance will be in circuit, while the two motors in series and the control will not "notch up." If it is necessary to slightly increase the speed the controller handle should be moved to the second point to start the automatic progression of the contactors through the resistance steps and quickly returned to the first or lap position. The notching up will be arrested, but the contactors which have picked up and cut out more resistances will remain closed. This manipulation of the controller handle may be repeated and a slow acceleration obtained when it is necessary. If the handle is left on the second point for a sufficient time all of the resistance will be automatically cut out of the motor circuit in successive steps under the control of the current limit relay until full series, or half speed, is reached.

39. When it is necessary to reverse the direction of the train movement the master controller handle should

be turned to the right. The first point in this direction is a switching point, similar to first point forward, and the train will move slowly without materially increasing its speed. If a higher speed is desired the handle should be moved to the second point and the automatic notching started for cutting out the resistance. It is possible to obtain only half speed in the reverse direction, as the second point leaves the motors in series relation.

40. Returning the master controller handle to the "off" position cuts off the supply of current to the train cable and contactors, and the latter therefore drop out and open the main circuit through the motors. Should the motorman from any cause remove his hand from the controller handle while it is at an "on" position a spring will return it to the "off" position and thereby automatically cut off power from the train and apply the air brakes. When the motorman turns to the "off" position it is necessary to hold down the knob in the controller handle to prevent the application of air brakes.

41. The controlling cut-out switch disconnects the operating parts of contactors, reverser and circuit breaker on the car from the train cable, but does not affect the operation of the rest of the train, although the car may be the one from which the train is being operated.

42. The arrangement of apparatus is such that the train may be operated in either direction from any master controller in the train. It is necessary, however, in order to operate in a reverse direction at full speed, to operate from a master controller at the end of a car toward the direction in which the train is to be moved.

43. Should the train break apart the control couplers will pull out, cutting off current from the train cable on the section of train behind the break. This drops out all

the contactors on the rear section, while the front section continues under the control of the motorman.

44. The control connections for the reverser are so arranged that unless the reverser is at the proper position current is cut off from the contactors, and, consequently, the motors on that car receive no current. When the reverser is in the correct position it is electrically locked and cannot be operated while the motors are taking current.

45. The wires of the master control circuit are all protected from damage due to excess current by means of small fuses. In case of electrical trouble within the master controller, train cable, couplers or connection boxes, the single fuse in the master controller switch will protect them. In case of trouble in the control circuit at contactors, reverser or circuit breaker, the fuses on the panel board will protect the circuit.

ELECTRIC LOCOMOTIVES.

A.—General.

46. The general remarks pertaining to the Sprague General Electric type "M" control, as applied to the Suburban Motor Cars (see paragraphs 1, 2 and 3), will also apply to the electric locomotive control, except that the train cable in the locomotive control has twenty wires, seventeen of which are connected to the master controller and to the motor control apparatus. Of the remaining three wires two are used for the sander device and one is an extra. This control, in the same way as on the Suburban Motor Cars comprises two distinct sets of circuits, namely, the main or motor control circuits and the master control motor circuits, the former being governed by the latter. Each locomotive has four motors, the control being arranged for operating the motors first, all in series, then in series parallel, and then in parallel relation. The two ends of locomotive are designed the "A" end and the "B" end, the main switch being located on the "B" end.

B.—Motor Control.

47. THE MOTOR CONTROL on each locomotive consists of the following apparatus:

Contactors.
Reversers.
Rheostats.
Main switch.
Main motor cut-out switches.
Individual motor fuses.

In addition to these pieces of apparatus there are four sets of third-rail contact shoes (two shoes in each set) and two overhead contact shoes, with the necessary main cables connecting them to the control apparatus on the locomotive. There is also a main cable extending through the locomotive terminating with couplers at the ends, so that the third-rail shoes and the overhead shoes of any two or more locomotives may be connected together. This cable is termed the Bus Line. The circuits from the contact shoes (both third rail and overhead) are protected by fuses, a set of two fuses in multiple being located near each shoe to protect the circuit of that shoe. From the third-rail shoes or from the overhead shoes the main circuit is carried through the respective fuses of each to the main switch and through the motor fuses to the contactors and thence to motors.

48. THE CONTACTOR (Fig. 504) is an electromagnet switch (see general description under paragraph 7, Suburban Motor Cars), with two contact arms and sets of contacts in multiple operated by one plunger. There are 43 of these contactors which are located in the end compartments of the cab, one group on each side of each end compartment. The contactors are suspended by insulating bolts from channel iron supports. The contactors are numbered progressively around the cab, No. 1 being the nearest the No. 1 reverser. Each contactor has a plate with its number, which is attached in front above the arc chute.

49. REVERSER (Fig. 505) (see general description, paragraph 9, Suburban Cars). There are two reversers; one in each end compartment. The No. 1 reverser, which is on the main switch end of the locomotive, has the armature and field leads of the two motors

on that end connected to the studs of its contact brushes. The connections of armatures and field leads for producing forward and backward movement of locomotive are established by means of copper bars pressed against spring contact brushes, through a toggle mechanism.

Fig. 504. Contactor for Large Current

50. THE MOTOR CONTROL RHEOSTATS (Fig. 506) are similar to those described under paragraph 10, Suburban Cars. These rheostats are located in four groups on the floor in end compartment of cab, under the contactors.

51. THE MAIN SWITCH (Fig. 507) is a knife-blade quick-break switch, with a lower mechanism for operating. The switch itself is enclosed in a box, lined

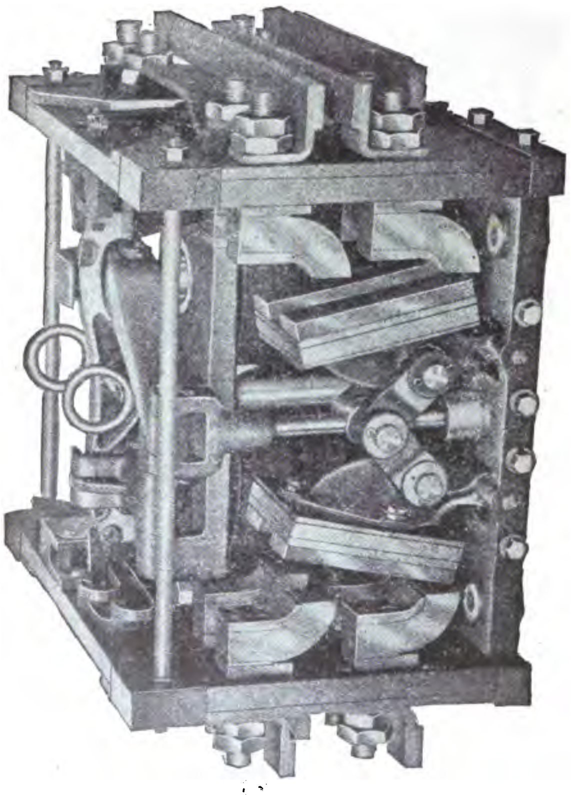


Fig. 505. Reverser for Locomotive.

with fireproof insulation, the handle for operating being located outside the box, where it is readily accessible. This switch is located in "B" end compartment of cab.

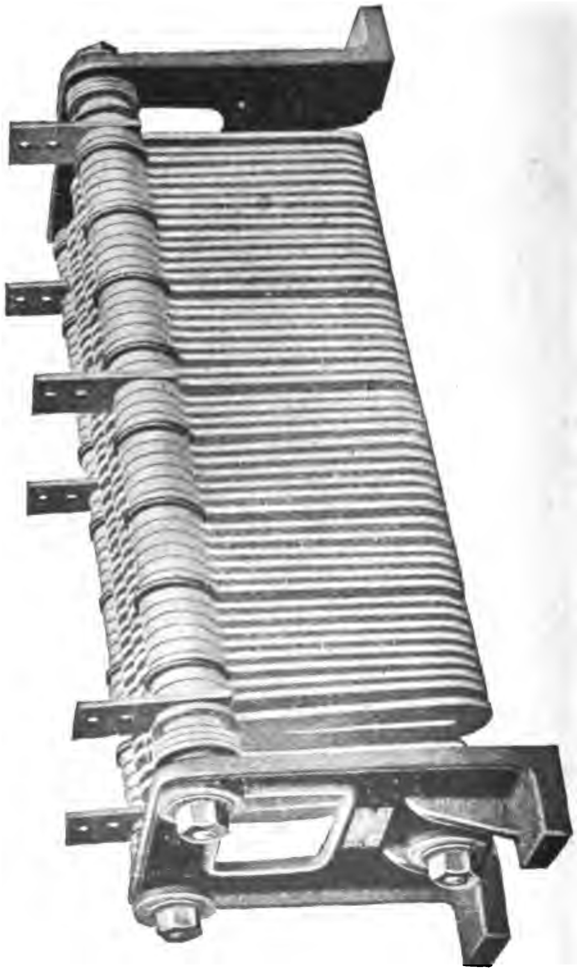


Fig. 506. Grid Resistance

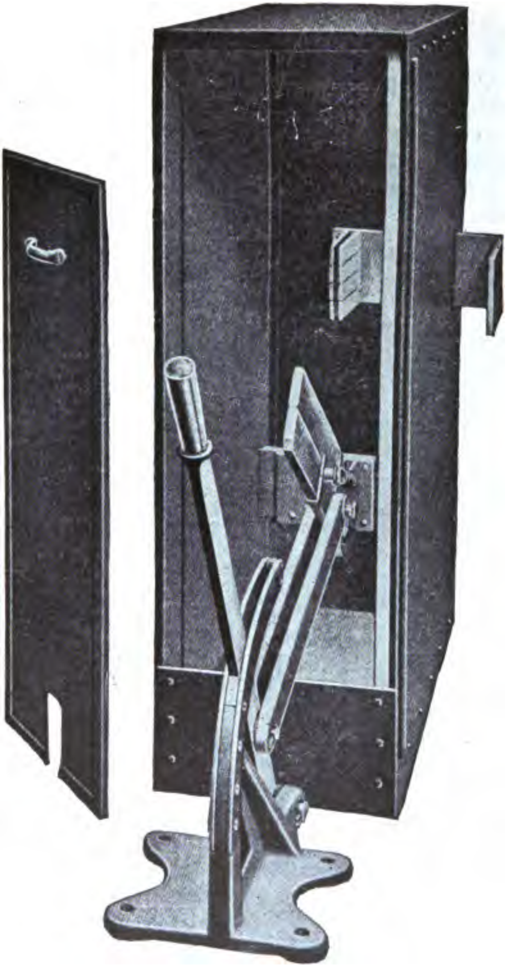


Fig. 507. Main Switch.

It should not be opened while current is on motors except in an emergency. It should, however, be opened before the individual motor fuses or contactors and reversers are examined.

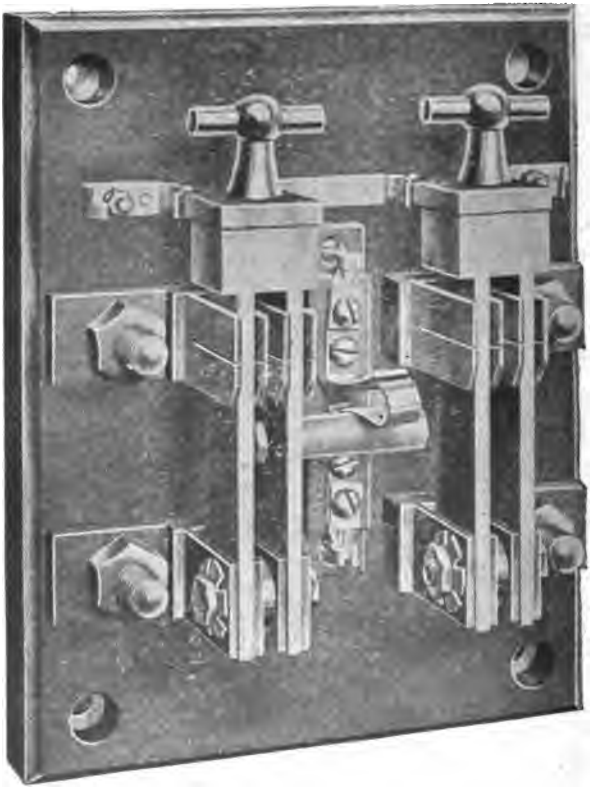


Fig. 508. Main Motor Cut-out Switches.

52. MAIN MOTOR CUT-OUT SWITCHES (Fig. 508) are for the purpose of cutting out the individual motors in case of any ground or defect in a motor which

renders it inoperative. There are four of these cut-out switches, one for each motor, and they are located on the sides of the cab, the switches for No. 1 and No. 2 motors being just over the No. 1 reverser and for No. 3 and No. 4 motors over the No. 2 reverser. The number of the motor to which it is connected is marked on each switch. Each switch also has a small auxiliary control cut-out switch which opens and closes with the larger switch for operating the circuit of the series contactor

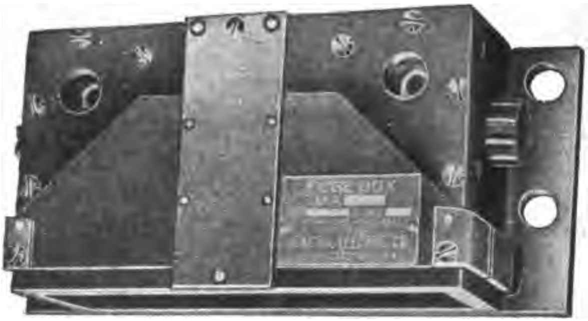


Fig. 509. Motor Fuse Box.

coils. These switches are normally kept closed, except in case of individual motor trouble. It should be seen that they are well closed, so that the small auxiliary switches make good contact. When one of these switches is opened on account of motor trouble, the locomotive will not move until controller handle reaches the eleventh notch.

53. MOTOR FUSE BOX (Fig. 509) (see paragraph 12, Suburban Cars, for general description of this type of fuse box). There are four of these fuse boxes,

each motor having its individual fuse. These boxes are located one over each third-rail shoe, just above the shoe fuse boxes. A copper ribbon fuse of 800 ampere rating is used in these boxes. Each box has marked on it the number of the motor whose circuit it protects.

Fig. 510. Third Rail Shoe Fuse Box.

54. THIRD-RAIL SHOE FUSE BOXES (Fig. 510) are similar to the motor fuse boxes, but somewhat larger. There are two of these arranged in multiple for each pair of third-rail shoes and are mounted on brackets just above their shoes. Copper ribbon fuse of 1,600 ampere rating is used in each of these boxes.

55. OVERHEAD SHOE FUSE BOXES are practically the same as those for third rail shoe, but are mounted on the roof, two in multiple near each other. A copper ribbon fuse of 1,600 ampere rating is used here also.

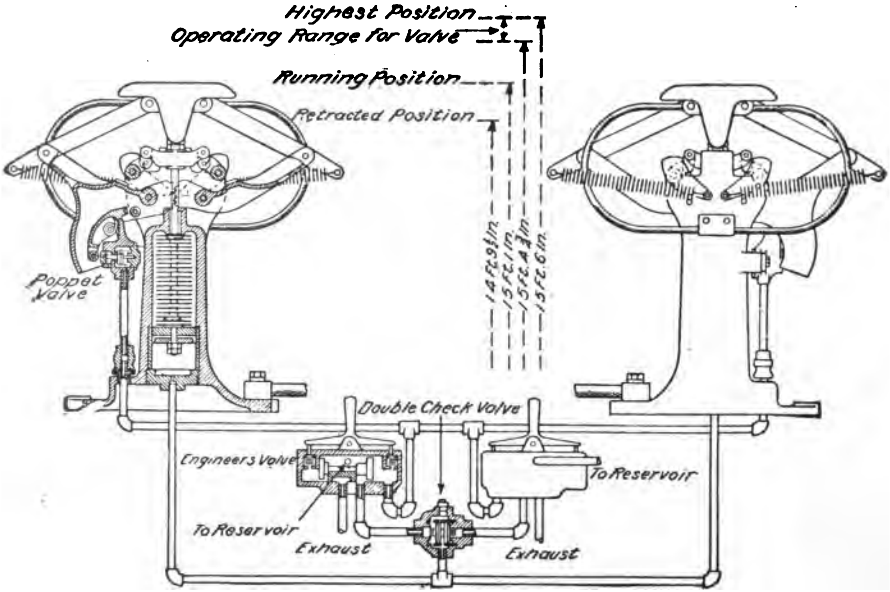


Fig. 511. Overhead Contact Device.

56. THIRD-RAIL CONTACT SHOES.—These shoes are of the "Slipper" spring actuated under-running type. The shoe bracket is mounted on a wooden insulating beam. There are two shoes in multiple on each bracket. Fig. 470.

57. OVERHEAD CONTACT DEVICE (Fig. 511) is a pneumatically operated shoe. There is a valve near each master controller in the cab, by means of which the

Fig. 512. Bus Line Coupler Socket.

shoe may be raised or lowered. When air is applied the shoe is lifted so as to make contact with the overhead rail. When air is released the shoe drops; also if the shoe runs off the rail it is tripped automatically and drops. Moving handle forward operates a pilot valve, by means of which a slide valve is thrown to admit air from reservoir to cylinder of contact shoe device. Pulling handle back operates another pilot valve and the slide valve is

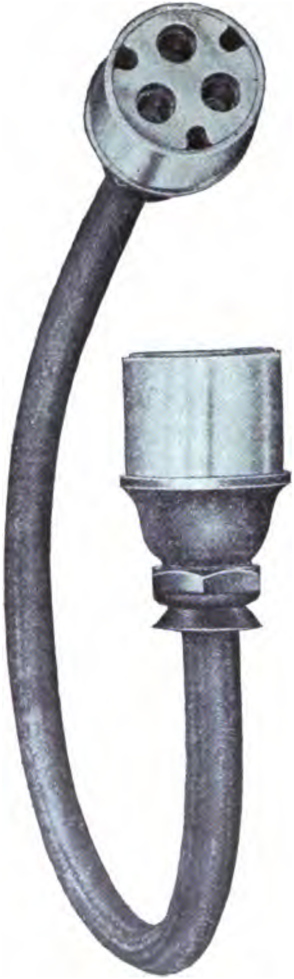


Fig. 513. Bus Line Coupler or Jumper.

thrown over to connect air chamber of contact device to exhaust. The handle will spring back to the middle position from either direction. There are two of these overhead contact shoes, which are controlled in common by either valve in the cab. They are mounted on wooden insulating blocks. It is very important that these shoes should not be raised when they will come in contact with overhead obstructions.

58. THE BUS LINE COUPLER SOCKET (Fig. 512) has three split plug contacts, which are connected together for obtaining sufficient carrying capacity. (See paragraph 14, Suburban Cars, for general description.)

59. THE BUS LINE COUPLER OR JUMPER (Fig. 513). (See paragraph 15, Suburban Cars, for general description.)

C.—Master Control.

60. THE MASTER CONTROL APPARATUS comprises the following for each locomotive:

Two master controllers.
One main master controller switch.
Two overhead master controller switches.
One negative control switch.
Train cable.
Four train cable coupler sockets.
One train cable coupler or jumper.
One train cable connection box.
One train cable cut-out switch, combining also a second train cable connection box.
One current limit relay.
Control fuses.

61. THE MASTER CONTROLLER (Fig. 514) contains two movable cylinders, which are geared together, and stationary contacts for each mounted on insulation supports. The function of the controller in general is to supply current at the will of the engineer to the train cable for operating the reversers and contactors. The primary or slow-speed cylinder operates the contactors which produce motor combinations. The secondary of high speed cylinder operates those contactors which cut out the main motor resistance. The secondary cylinder is geared to primary at the ratio of about three to one. Geared to cylinders is a governor device, by means of which the movement of the controller handle and the cylinders is checked when current through the motors exceeds a certain amount. The controller has a separate reverse cylinder, and there is a separate handle for this. The reverse handle can be thrown only when the controller handle is in the "off" position. The "off" position of the controller handle is indicated and is the extreme forward position of handle. There are twenty-four operating notches and an "off" point on the controller dial ring. A latch on the handle engages the notches on the dial ring and has to be released in moving from notch to notch. The first ten operating notches are for series, the next seven for series parallel and the next seven for parallel operation of motors. The tenth notch is full series, the seventeenth full series parallel and the twenty-fourth full parallel position of motors, and at all other points motors will have resistance in circuit.

62. MAIN MASTER CONTROLLER SWITCH (Fig. 503) is located on side of passage way in "B" end compartment of cab and is used for admitting current to master controllers and should be closed to operate from

either master controller. The main purpose of this switch is to cut off line from the master controller fuse, which is located in this switch, in case the fuse has to be inspected or renewed. The fuse for this switch is 25 ampere capacity.

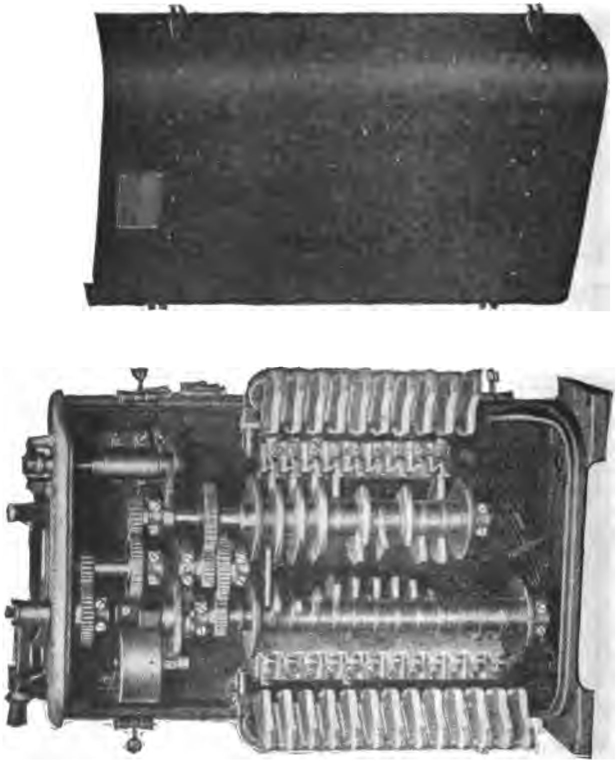


Fig. 514. Master Controller.

63. THE OVERHEAD MASTER CONTROLLER SWITCHES (Fig. 494) are located one over each master controller and are used for admitting or cutting off cur-

rent from the controller over which it is located. THE NEGATIVE CONTROL SWITCH (Fig. 494) is located on the side of the passage way of the "A" end.

Fig. 515. Train Cable Coupler Socket.

Opening this switch cuts off ground from the reverser and contactor coils. It must be kept closed for operation. Ordinarily it need not be touched.

Fig. 516. Train Cable Coupler Plug.

64. The TRAIN CABLE is composed of twenty conductors, which are attached to numbered plugs in the coupler sockets, and there are branches from seventeen of these wires extending to the master controller. These seventeen wires are used as follows:

No. 1.—For operating series contactors.

Nos. 2 and 5.—For operating series-parallel contactors.

No. 3.—For operating bridge contactors.

Nos. 2 and 4.—For operating parallel contactors.

Nos. 6, 7, 10, 11, 12, 13, 14, 15 and 16.—For operating resistance contactors.

No. 18.—For operating controller governor.

No. 0.—For operating reverser one direction.

No. 8.—For operating reverser other direction.

Nos. 19 and 20 are used for operating the sander device.

No. 17 is an extra wire.

65. THE TRAIN CABLE COUPLER SOCKET (Fig. 515) has twenty contact studs otherwise the general description, paragraph 23, Suburban Cars, will apply to this coupler socket.

66. THE TRAIN CABLE COUPLER PLUG (Fig. 516) has twenty contacts to agree with coupler socket. (See general description, paragraph 24, Suburban Cars.)

67. TRAIN CABLE CONNECTION BOXES are used for making connections from master controller and coupler sockets to the train cable. One of these connection boxes (Fig. 517) is combined with the twenty-point cutout switch. This is mounted on the back of the master controller on the "A" end of the cab. This is the No. 2 connection box. The plain connection box (Fig. 518) is

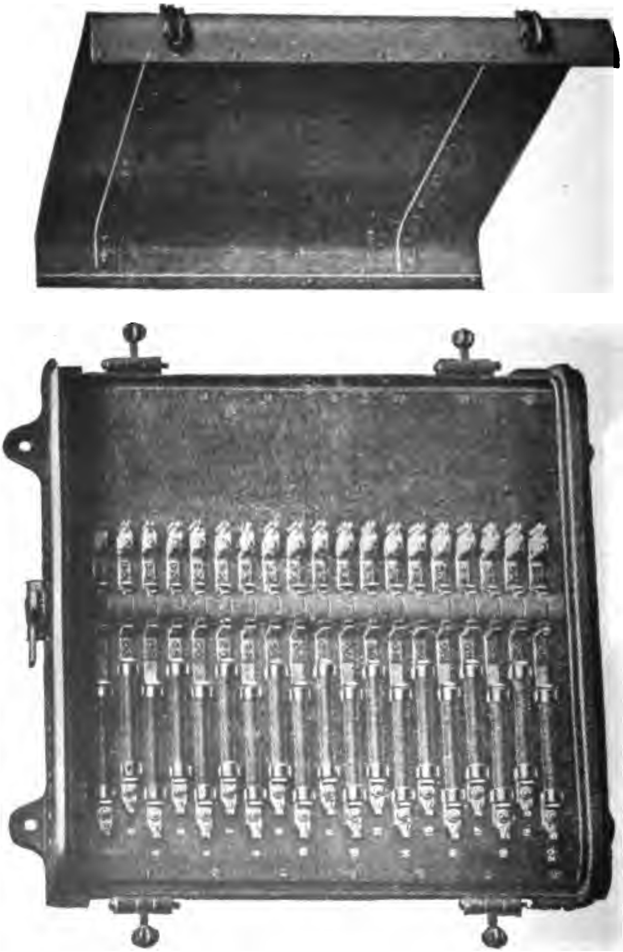


Fig. 517. Train Cable Connection Box.

mounted on the back of the controller at "B" end of the cab. No. 0 wire from No. 1 box connects to No. 8 wire in No. 2 box, and No. 8 from No. 1 box connects with No. 0 in No. 2 box. All other wires connect number to number. One of the wires in the outside layer is covered

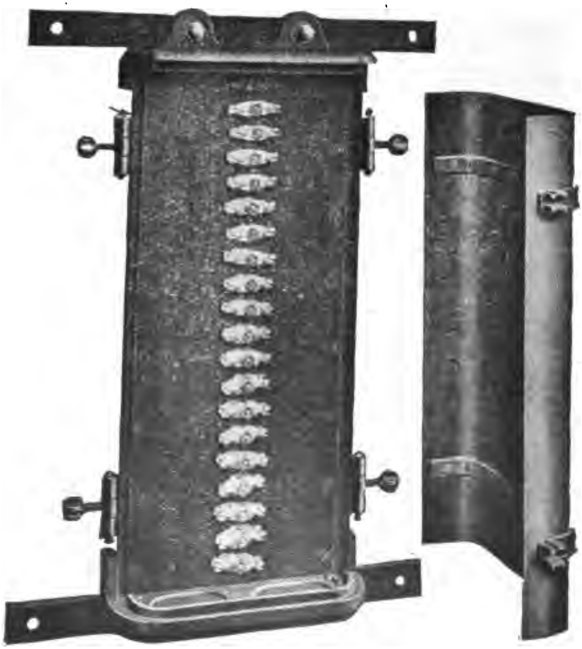


Fig. 518. Plain Connection Box.

with green braid. This is No. 1 wire, the other wires of this layer being numbered in the counterclock-wise direction from this. The red covered wire in the inner layer is No. 14, the others being numbered counterclock-wise direction.

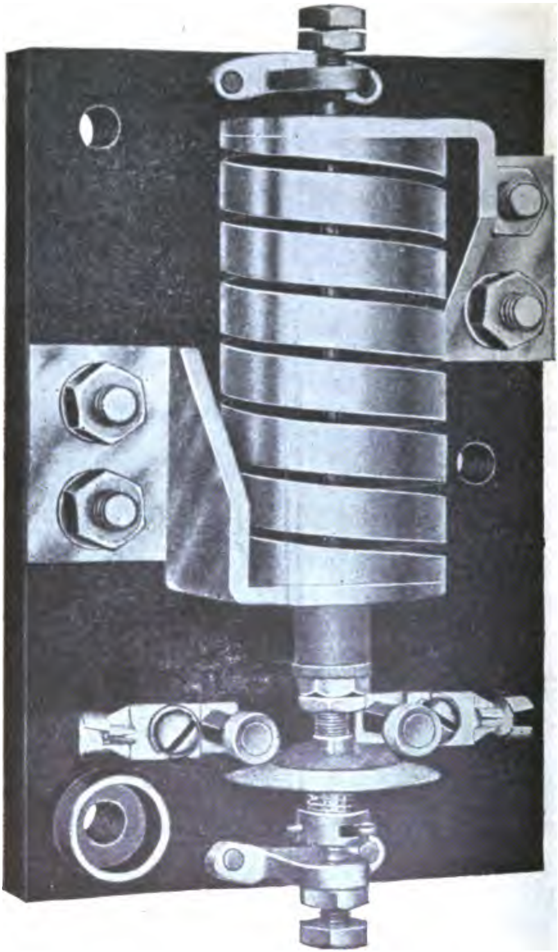


Fig. 519. Current Limit Relay for Locomotive.

68. THE CURRENT LIMIT RELAY (Fig. 519) is located just above the No. 1 reverser and is provided for the purpose of checking a too rapid movement of the controller handle in getting the train up to speed. The relay coil is connected in series with No. 2 motor circuit. If the current through the motor exceeds a certain amount, the plunger of relay picks up and closes a set of contacts which supplies current to the controller governor. The controller handle is thus held from being moved on and cannot be moved another notch until the current through the motor falls to a certain amount.

69. THE CONTROL CUT-OUT SWITCH (Fig. 517) has already been referred to under the subject of CONNECTION BOXES. The connection studs of this box also serve the purpose of the No. 2 connection box. This cut-out switch serves the purpose of disconnecting the control circuits of contactors and reversers on a locomotive from the train line. The cut-out switch has twenty sets of contacts which are connected or disconnected accordingly as the handle is full around to the left or to the right.

70. CONTROL FUSES (Fig. 517) are mounted on the same insulation back as the cut-out switch and are contained in the same box. The fuses numbered from the top protect the following circuits:

No. 1—Series contactor coils.

Nos. 2 and 5—Series parallel contactor coils.

Nos. 2 and 4—Parallel contactor coils.

No. 3—Bridge contactor coils.

Nos. 8 and 9—The reverser operating coils.

Nos. 6, 7, 10, 11, 12, 13, 14, 15 and 16—The resistance contactor coils, respectively, one fuse protecting the contactor coils for each resistance step of controller.

No. 17 is not required but is extra.
No. 18—Controller governor circuit.
Nos. 19 and 20—Sander circuits.

D.—Air-Compressor Control.

71. The air-compressor control comprises the following pieces of apparatus:

A pump motor switch.
A pump governor.
A pump motor circuit contactor.

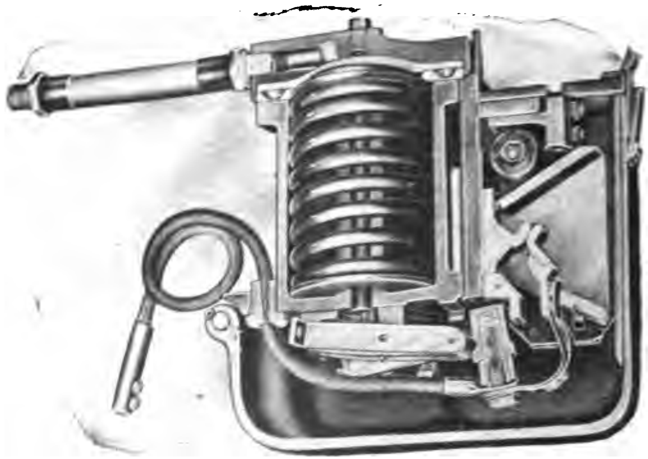


Fig. 520. Sectional View Air Pump Governor.

72. PUMP MOTOR SWITCH (Fig. 503) is located on side of passage "A" end compartment. This switch is for the purpose of opening the pump motor circuit when locomotive is not in service. This switch contains a 40-ampere fuse, which protects the pump motor circuit.

73. PUMP GOVERNOR (Fig. 520) is located in "A" compartment on side opposite No. 2 reverser. The

governor is of the diaphragm type of construction, the movement of the diaphragm, as air pressure falls or rises, operating a lever mechanism which serves to give a quick make and break to a small switch of the contactor type. This switch does not close the pump motor circuit itself, but closes the circuit through the PUMP MOTOR CIRCUIT CONTACTOR, which has higher current capacity on its contacts than the governor. This contactor is located to the left of the governor. When the air pressure in the reservoir falls to 130 pounds, the governor closes its contacts, thereby energizing the contactor coil, which in turn closes its contacts; the pump motor circuit being thus completed the pump starts. When the air pressure reaches 140 pounds the governor opens the circuit of the contactor coil, which in turn opens and breaks the pump motor circuit and the pump stops.

But the governor and the contactor have strong magnetic blow-outs at their contacts, sufficient to handle any current which they may take in this service.

E.—Track Sander Control.

74. The track sander control comprises the following pieces of apparatus:

One main sander switch.

Two sander operating switches.

Two electro-pneumatic valves.

75. MAIN SANDER SWITCH (Fig. 503) located in the "A" end compartment of cab, is for the purpose of admitting or cutting off current from the sander operating switches. This switch contains a 10-ampere fuse. The switch should be opened on inspecting fuse. This switch has plate marked "Sander."

76. SANDER OPERATING SWITCHES (Fig. 521) are located one on side of cab near each master controller. These are double-throw switches and are marked "Sand Forward," "Sand Reverse." Moving

Fig. 521. Sander Operating Switch.

handle to the "Forward" position energizes the valve which will apply sand to rail for forward direction. "Reverse" position of handle will apply sand for the reverse direction.

77. ELECTRO-PNEUMATIC VALVES (Fig. 522) are located one in each end compartment. One valve operates a sander for one direction of movement, the

other valve operates a sander for the other direction, only one valve being operated at a time. The valve is operated by a magnet which is energized by current applied in the sander operating switch.

F.—Train Operation—General.

78. Before attempting to start the locomotive of train the motorman should first close the pump switch, then close the main switch and see that the main control switch and all the cut-out switches are closed. After the reservoir and train line are charged the overhead control switch over the controller from which locomotive is to be operated should be closed and the reverser handle thrown in the direction of desired movement of locomotive. The motorman may then proceed on the signal..

After releasing the latch on controller handle pull controller handle to the first notch, then to the second notch, and so on, until the desired speed is attained. For coupling, with the locomotive, light, the first or second notches will ordinarily be sufficient. If it is desired to get up to speed as soon as possible the handle may be moved around notch by notch, allowing the latch to take each notch until the last notch is reached.

If the motorman feels at any point, the further movement of the controller checked, he should not exert undue pressure on handle—no more than is ordinarily required to move the handle from one notch to the next. Whenever the current through the motors is higher than a certain amount the automatic governor acts and stops the further movement of handle. When the current falls to a certain amount the governor releases controller cylin-

ders and another notch may be taken, and so on. Every notch on the controller should invariably be taken by latch in moving controller on, whether in accelerating or in throwing controller on with motors already up to

Fig. 522. Electro-Pneumatic Sanding Valve.

speed. In throwing off, the notches need not be observed.

The "off" notch of the controller may be called the zero notch. The first closed position of the controller is the first notch and so on, the tenth notch being the full series

position, the seventeenth notch the full series parallel position and the twenty-fourth notch the full parallel position. The tenth, seventeenth and twenty-fourth notches may then be called running points. The intermediate points are resistance points and should ordinarily be used only for accelerating or switching. The tenth notch gives one-quarter speed, the seventeenth notch one-half speed and the twenty-fourth notch full speed. The transition from the tenth to the eleventh notches and from the seventeenth to the eighteenth should be made promptly, without pause between.

When the controller is on any notch the current passes from the master controller switch through the master controller of the train cable of one or two locomotives and thence to the reverser operating coils and the contactor coils, which correspond to the given notch, as shown in the following table. This table give the numbers of the contactors which are closed on each step of the master controller. The numbers that are underscored indicate the contactors which are closed on that step in addition to previous ones.

Controller Steps.	Contactors Closed.
1	1-2-4-19-22-25-33-41-42
2	1-2-4-$\underline{18}$-19-22-25-33-41-42
3	1-2-4-18-19-22-25-33-$\underline{39}$-41-42
4	1-2-4-18-19-22-25-$\underline{31}$-33-39-41-42
Series.......5	1-2-4-$\underline{5}$-$\underline{13}$-18-19-22-25-$\underline{26}$-31-33-$\underline{34}$-39-41-42
6	1-2-4-5-$\underline{6}$-13-$\underline{14}$-18-19-22-25-26-$\underline{27}$-31-33-34-$\underline{35}$-39-41-42

7	1-2-4-6-7-14-15-18-19-22-25-27-28-31-33-35-36-39-41-42
8	1-2-4-7-8-15-16-18-19-22-25-28-29-31-33-36-37-39-41-42
9	1-2-4-8-9-16-17-18-19-22-25-29-30-31-33-37-38-39-41-42
10	1-2-4-9-10-17-18-19-22-25-30-31-33-38-39-41-42
First Bridge.	1-2-4-11-19-25-32-33-41-42
11	1-2-4-11-18-19-21-23-25-32-33-39-41-42
Series Parallel..12	1-2-4-5-11-13-18-19-21-23-25-26-32-33-34-39-41-42
Series Parallel..13	1-2-4-5-6-11-13-14-18-19-21-23-25-26-27-32-33-34-35-39-41-42
14	1-2-4-6-7-11-14-15-18-19-21-23-25-27-28-32-33-35-36-39-41-42
15	1-2-4-7-8-11-15-16-18-19-21-23-25-28-29-32-33-36-37-39-41-42
16	1-2-4-8-9-11-16-17-18-19-21-23-25-29-30-32-33-37-38-39-41-42
17	1-2-4-9-10-11-12-17-18-19-21-23-25-30-31-32-33-38-39-40-41-42
Second Bridge	1-2-4-12-19-21-23-25-33-40-41-42
18	1-3-4-19-20-21-23-24-25-33-41-43

Parallel....19 1-3-4-5-13-19-20-21-23-24-25-26-33-34-41-43

20 1-3-4-5-6-13-14-19-20-21-23-24-25-26-27-33-34-35-41-43

21 1-3-4-6-7-14-15-19-20-21-23-24-25-27-28-33-35-36-41-43

22 1-3-4-7-8-15-16-19-20-21-23-24-25-28-29-33-36-37-41-43

23 1-3-4-8-9-16-17-19-20-21-23-24-25-29-30-33-37-38-41-43

Parallel....24 1-3-4-9-10-17-18-19-20-21-23-24-25-30-31-33-38-39-41-43

If the reversers are not already thrown to the position corresponding with the position of the reverser handle, when the controller is thrown to the first notch, current will first pass through the proper operating coil to ground. After the reversers have reached the correct position interlocking contacts on each reverser cut off current to ground and establish a circuit through three contactor coils. Moving the reverse handle does not operate the reversers, but simply arranges the contacts, so that when the controller is turned to the first position reversers will be thrown in the proper direction. The operating coil for one direction on one reverser is in multiple with the corresponding coil on the other reverser, these two coils being controlled by one wire from the master controller and protected by one fuse.

On the first notch the main or motor current flows from the third-rail shoes or from the overhead shoes through the shoe fuses to the main switch, then through

the No. 1 motor fuse, through the reverser and No. 1 motor, through a set of rheostats to reverser and No. 2 motor, then through the other reverser and No. 3 motor through a set of rheostats, then through another set of rheostats to reverser and No. 4 motor and then to ground. The four motors are here all in series, with all the resistance in circuit; and the locomotive, if light, may start, or if coupled to a train may simply take up draw-bar slack. Each of the next three steps cuts out one complete set of motor resistance, and on succeeding steps, until full series is reached, the remaining set is cut out in six more steps. After full series, between the tenth and eleventh notches, bridge connections are established, and then on the eleventh notch motors are thrown in series parallel relation. Resistance is cut out in six steps to full series parallel, the seventeenth notch. Bridge connections are then established and motors are then thrown all in parallel, the resistance being cut out again in six steps. When motors are in parallel each is protected by its own fuse.

When it is necessary to reverse the direction of train movement, leaving controller handle in the off position, throw the reverser handle in the opposite direction and then move controller handle on in the same way. The reverser handle is to be thrown in the direction corresponding to direction of movement required. The motors should not be reversed while the locomotive is moving, except in case of emergency and then if speed is more than a few miles per hour the wheels would probably slip. If it is necessary to reverse while moving, do not throw controller handle beyond the first notch, if all the motors are cut in, or beyond the eleventh notch if one motor is cut out.

When operating on an overhead rail section the overhead contact shoe will be tripped and will drop on leaving this section. The motorman should, however, as an extra precaution, throw the valve handle back. Either for raising or lowering the overhead shoe it is necessary to hold handle in position only long enough for the shoe to start movement.

To sand the rails the SANDER OPERATING SWITCH should be moved over in the direction of movement of the locomotive. To stop the sand the handle of this switch must be brought back to the middle position.

The control cut-out switch, if open, disconnects the operating parts of contactors and reversers on the locomotives from the train cable, but does not affect the operation of the other locomotive if two are connected together, although it is cut out on the locomotive whose master controller is being operated. The control connections for the reverser are so arranged that unless it is at the proper position current is cut off from contactors, so that motors on that locomotive will receive no current. In case of electrical trouble within the master controller train cable, couplers, or connections boxes, the single fuse in the master control switch will protect them. In case of local trouble on contactors or reversers the fuses in the cut-out switch will protect the circuit.

AIR-BRAKE EQUIPMENT ON MOTOR CARS.

A.—General.

The air brakes on the cars and locomotives in electric service are essentially the same as those on the other passenger equipment, except that the steam driven air pumps on the locomotives are replaced by electrically driven air compressors, one on each electric locomotive and each motor car, and the design of the air brakes is such that their release, as well as application, can be graduated.

The use of an air compressor and main reservoir on each motor car necessitates the use of an additional train pipe to connect all the main reservoirs together and to the motorman's brake valve. This extra train pipe is called the control pipe.

A safety valve is placed in the end of the main reservoir on each motor car to prevent overcharging the brake system in case the electric pump governor fails.

B.—Hints to Motormen.

In suburban service it is highly important not to block the road. Therefore, remember in case anything gets out of order that the first important thing is to get out of the way; learn carefully just what to do in order to make the proper move quickly; for example:

1. In case of a burst hose, if it be the control pipe hose, the cut-out cock on both sides of it should be closed; but if it should be the brake pipe hose, then it is neces-

sary to close the cut-out cock ahead of the brake and the double cut-out cocks on each of the cars back of it; then open, and leave open, the auxiliary reservoir bleed cocks on all of the cars that are cut out. In a case of this kind some one would be designated and prepared to operate the hand brakes on the cars that are cut out in case a car coupling should break and cause the train to separate.

2. In case of inability to release a brake, caused, for instance, by the emergency valve remaining unseated after an emergency application, close double cut-out cock and open and leave open, bleed cock of auxiliary reservoir on this car and proceed.

3. In case of brake sticking after service application, make about a ten-pound reduction and place the handle of the brake valve in release position. This will usually release the brake. If not, or further trouble is had with this brake, do as recommended in preceding case 2.

It will be seen by these examples that by a knowledge of the operation of the air-brake the motormen and trainmen can formulate rules for themselves that, in case of trouble, will enable them to get out of the way with little or no delay.

To gain time adapt the brake-pipe reduction, or application of brakes, to speed. For example, for high speed made a full application and graduate off when a short distance from the stop. To handle train smoothly make the application heavy and soon enough, so that if held on the train would stop a car length or so short of the mark. Then as the stop or mark is approached graduate the pressure out of the brake cylinder so that little remains when stop is made. If on a level, complete the release; if on a grade, hold until the signal to start is given, then release. As the pressure has been graduated down so

that little remains in the cylinder, it will be seen that the start can be made promptly.

As the automatic brake is applied by the reduction of the brake-pipe pressure, no matter how produced, it is plain that leaks will produce results not intended or desired by the motorman, and sometimes interfere with the accuracy and smoothness of the stop. Therefore, they should be kept down and reported as surely and promptly as any other defect. Motormen should observe as carefully as possible the action of the governor, feed valve and gauges; that is, their adjustment, etc., as much better operation can be obtained if all are approximately uniform.

One of the things that the motorman should learn carefully regarding the automatic brake is, that after a certain reduction of pressure in the brake pipe, say eighteen to twenty pounds, the auxiliary reservoir and brake cylinder have equalized. Therefore, no greater braking power can be obtained, and to further reduce the brake pipe pressure wastes a great amount of air which must be restored to the brake pipe before a release can be made, and interfere with that release to such an extent that a rough stop is usually the result.

Properly handled this brake possesses all the flexibility of the straight-air brake, while the safety and reliability of the automatic brake has been greatly increased. Therefore the motorman should endeavor to understand its principles, so that he can handle the brake so as to obtain its maximum efficiency with credit to himself and comfort to the passengers.

AIR COMPRESSOR ON ELECTRIC LOCOMOTIVES.

A.—General.

The CP-19-B air compressor consists of a duplex, single-acting, vertical air pump, located between and directly connected to two 8-pole series, direct-current motors. It has a piston displacement of 75 cubic feet per minute, when operating on 600 volts, and against a tank pressure of 130 pounds per square inch. Fig. 523.

The compressor frame is so shaped as to form a large oil chamber for the cranks and connecting rods. It is provided with a pedestal-like base, arranged to support the machine, and bolted to the floor of the locomotive cab. To this frame the motor frames are bolted, one to each end. The vertical cylinders are bolted to the top, and large oil-tight doors are provided, one on each side, for admission to the cranks and bearings.

The pistons are provided with single rings of the three-section type. Each cylinder is provided with independent intake and exhaust valves. These valves are of the tubular type, operating in a vertical position on the tops of the cylinders.

The intake for the air is provided with a copper screen, located in a box, which can be easily removed and cleaned when necessary.

The crank chamber is provided with baffle plates, above and below, for the purpose of preventing too much splashing of oil into the cylinders.

The armatures are fastened directly to the crank shaft. Each end of the shaft is tapered and supplied with key and clamping nut, for the purpose of securing the armatures and providing means for their removal.

The pole pieces are made of soft iron sheets, securely riveted together and bolted to finished surfaces on the inside of the motor frame.

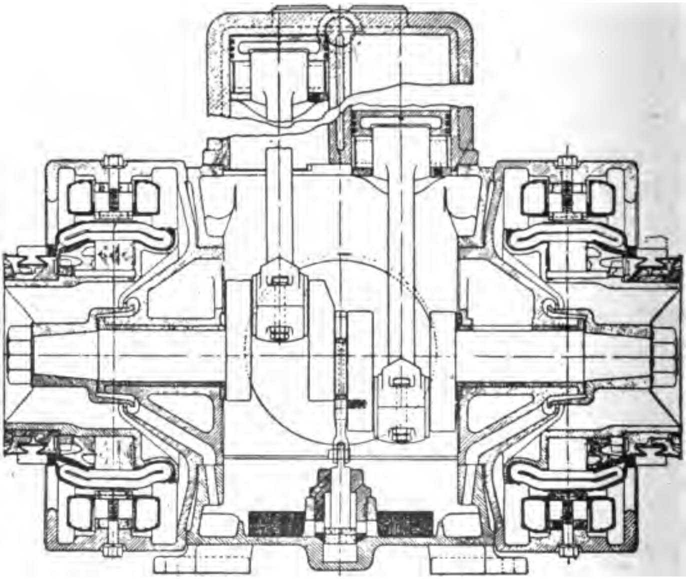


Fig. 523.

The brush holders are supported on insulated radial studs held by clamps bolted to the ends of the motor frames in such a manner as to permit adjustment to accommodate the wear of the commutator. The outside end of each motor is provided with a large ventilated

shield, semi-closing the machine, and affording protection for the armatures and brush holders.

The machine has a total of six bearings, consisting of one crank bearing, and one wrist bearing for each of the two connecting rods, and two main bearings. The main bearings are located in the motor frames, one on each side of the crank portion of the driving shaft. All bearings are provided with removable bronze linings. The connecting rods are split on the diameter of the crank pin, and the crank bearings are held in place by caps bolted to the lower ends of the connecting rods. The main bearings are oiled from waste packed pockets formed in the motor frame castings. The crank bearings are lubricated by oil splashed by the connecting rods. The wrist bearings are lubricated by oil supplied to them through pipes connected to pumping devices located on the lower ends of the connecting rods so as to dip into oil in the bottom of the crank chamber.

B.—Operation.

The CP-19-B air compressor is intended to operate on 600 volts, and for such operation the motors should always be connected in series.

The direction of rotation of the armatures should be such that the top side of the commutator travels toward the observer, when standing on the side of the compressor where the air intake is located, and the intake openings in the oiling devices should recede while sweeping through the oil.

Should it be necessary to remove an armature, take off the end shield and remove brush holders; then take off the armature nut. Before removing the nut, it will be

necessary to straighten out lock washer underneath the same. When the nut has been removed two bolts of proper length, with hooked ends, should be hooked behind two spokes of the armature spider diametrically opposite each other. The outside ends of these bolts should be threaded, and should pass through holes in a piece of iron, held against the armature shaft in such a manner that when tightened the armature will be loosened and pulled off.

When it becomes necessary to replace a lining for a main bearing it will be necessary to remove the armature and armature key. The lining can be then drawn out of the motor frame over the shaft by bolts screwed into tapped holes in the end of the lining.

As the commutator wears down it may become necessary to adjust the brush holders. The brush *holders* should be located about one-eighth of an inch from the commutator, and can be adjusted by loosening clamping bolt so the supporting stud can slide in the clamp.

In replacing brush holders which have been removed, care should be taken to move them over as far as possible in the direction opposite to the rotation of the commutator, so as to produce sparkless commutation.

If it should be observed that a compressor appreciably increases its speed, from causes other than increase in voltage, and seems not to be delivering the proper amount of air, attention should be given to the intake valves, as such a condition might be caused by valves sticking, or not properly seating due to accumulation of dirt. The valve in question should be taken out and thoroughly cleaned, care being taken not to leave particles of thread or lint sticking to it.

Should the intake valves fail to open with every stroke on the compressor, attention should be given to the exhaust valves. If the exhaust valves leak, or remain open for any reason, the cylinder will receive air from the reservoir, and will not give the intake valves an opportunity to open. When these valves are out care should be taken not to drop dirt into the cylinders, as the clearance between tops of cylinders and pistons is very small.

Valve trouble of any kind rarely happens with this type of valve, and can be caused only by accumulation of dirt. The operator will soon learn to know from the peculiar click of the valves whether or not they are working properly.

Should it become necessary to remove a piston or connecting rod, the cylinders must be taken off, then the crank caps removed from the connecting rods, upper baffle plate removed, and connecting rod and piston drawn upwards out of the compressor frame.

Oil should be maintained in the crank chamber to within about one-half inch of the centre portion of the lower baffle plate, and should never be allowed to become so low as not to permit the oiling device to properly dip into the same.

The frame of the machine is designed to catch oil splashed in the crank chamber and deliver it to the main bearings. However, the waste pockets around these main bearings should be examined from time to time to see that the waste is tight against the shaft, and is receiving the proper amount of oil. If splashing fails to supply oil to these bearings, the pockets should be filled by hand once a week.

Oil in the crank chamber should not be too thick, but should be of medium or light weight so that the oiling

device can work to the best advantage. A light gas engine cylinder oil is recommended. When the oil in crank chamber becomes muddy it should be removed and replaced by a fresh supply.

Should pounding develop in the compressor, the crank bearings should be inspected, and if found in good condition, it is probable that the cylinder clearance has filled with dirt, or wrist bearings have become defective, and the cylinders should be removed and cleaned and bearings inspected.

In replacing pistons in cylinders care should be taken not to omit any of the little springs in the piston rings.

The machine should be thoroughly inspected from time to time, and bearings should not be allowed to become excessively worn before being replaced.

Brushes should be replaced when worn out, and commutators should be kept smooth, clean and round. Care should be taken not to allow oil to come in contact with the commutator or windings, as oil is injurious to insulating materials.

SUBURBAN MOTOR CAR CATECHISM—CAUSES FOR FAILURE OF TRAIN MOVEMENT.

Question 1. If train fails to move after instructions under train operation have been followed, what should be done?

Answer. Light circuit switches should be closed to ascertain if there is power in the contact rail, or motorman should note if trains in neighborhood are moved by power.

Question 2. If it is found that there is current in operating car, what should be done?

Answer. Master controller handle should be moved to first point, then master controller switch opened to ascertain whether the master control circuits are closed, which will be indicated by the sound of slight arcing at master controller switch.

Question 3. What would cause the failure of train cable circuits?

Answer. First, imperfect master controller fuse. Second, grounded train cable. Third, imperfect contact in master controller. Fourth, loose coupler jumper.

Question 4. What should be done to detect imperfect fuse?

Answer. Insert new fuse, and if this fails it is evident the trouble is elsewhere.

Question 5. What should be done when a grounded train cable occurs?

Answer. The master controller fuse should be replaced and the controller moved to the "on" position to determine if fault lies in construction of the fuse. If this fails, an attempt should be made to locate the ground in the train cable. The first thing to do is to throw the CONTROL CUT-OFF SWITCH (Fig. 502) on the operating car to the "off" position. If this proves ineffective, this operation should be repeated back through the train, cutting out, however, the train cable jumper between car tested and one to be tested.

Question 6. What should be done to detect imperfect contact in master controller?

Answer. Motorman should remove cover from controller and note the movement of contact fingers. The action of the train is dependent upon the contact of these fingers, and if it is found that the contact is imperfect he should endeavor to readjust the contacts, and if he fails in this it is then necessary to operate the train from the next car.

Question 7. What should be done to detect a loose jumper?

Answer. Motorman should lose no time in going back through his train to determine if the coupler plugs are properly inserted in the sockets, and, if not, he should insert them properly.

Question 8. What are the other causes that would prevent the operation of a train or reduce the speed?

Answer. First, the blowing of third-rail shoe fuses. Second, the blowing of main motor circuit fuses. Third, the blowing of circuit breakers or main fuses. Fourth, an imperfectly acting triple valve causing brakes to remain set on one or more cars in train.

Question 9. How can enclosed fuse that is blown be detected?

Answer. If an enclosed fuse has blown there is a deposit or collection of greyish powder at the ends of the box.

Question 10. What should be done in the event of a third-rail shoe fuse blowing?

Answer. This fuse will blow only when there is a short circuit on the car equipment, and fuse should not be replaced but train continued in the regular manner, and report promptly made to the train despatcher or person in charge of nearest terminal.

Question 11. If a circuit breaker acts or blows, what should be done?

Answer. The circuit breaker setting switch should be moved to the "on" position.

Question 12. What should be done when a triple valve acts imperfectly?

Answer. Air-brake instructions should be followed, i. e., valves should be cut out and auxiliary reservoir cock opened to release brakes.

Question 13. If a train is standing on crossover and current cannot be obtained on the operating car, although the other cars of the train and trains in the neighborhood have current, what does this indicate?

Answer. This indicates that the bus line fuses between the operating and adjacent cars have blown, or that bus jumper is loose or disconnected.

Question 14. What should be done to continue operation of train?

Answer. Motorman should go back to the first motor car where current can be obtained and move train through crossover, then go back to the first car again

and proceed in the usual manner until a point of inspection can be reached and inspector notified.

Question 15. If a fire occurs in any car in the train, what should the motorman do?

Answer. Open all circuit breakers by moving the circuit breaker switch (Fig. 485) to the "off" position, and if this fails he should then open the main or motor circuit switch and the main cut-out switch on the car on which the trouble occurs.

Question 16. If smoke or fire is observed by the trainmen in any of the light or heater circuits within the car, what should be done?

Answer. The trainman should immediately cut out the light or heater switches, whichever the case may be, and the trouble be reported to the despatcher in charge of the nearest terminal.

Question 17. If an unusual noise is observed in the movement of train, what should be done?

Answer. To prevent delay the motorman should have the conductor stand beside the train to locate the noise while he moves the train, after which, if the trouble is with the brake rigging, same should be tied up.

Question 18. If the noise is located within the motors, what should be done?

Answer. Motorman should open the cut-out switch on the car affected, and proceed after reporting trouble to despatcher in charge of terminal.

Question 19. If a third-rail shoe support is broken, what should be done?

Answer. Motorman should first pull the bus line jumpers, at both ends of the car, insert wooden insulating slippers between the contact shoe and rail and then proceed to detach or tie up remnants of device, exercis-

ing extreme care that the contact device is kept clear of the truck frame, contact rail, structure, or any grounded parts to prevent injury to himself.

Question 20. If either pilot or emergency air-brake valve leaks badly, what should be done?

Answer. First try applying brakes by releasing the knob in the controller handle several times, and if this does not remedy the defect or difficulty cut the valves out by means of a cut-out cock located in the pipe leading to them from the train line.

ELECTRIC LOCOMOTIVE CATECHISM. CAUSES OF FAILURE OF TRAIN MOVEMENT.

Question 1. If locomotive fails to move after instructions under train operation have been followed, what should be done?

Answer. First, after making sure that the overhead and main master controller switches are closed, throw controller on two or three points and off, and observe by the sound whether any contactors are operating.

Question 2. If none of the contactors operate, what should be done?

Answer. Turn on light circuit switches to ascertain if there is power on the third rail or overhead rail.

Question 3. With current on the locomotive, what would cause the failure of contactors to operate?

Answer. First, an imperfect master controller fuse. Second, imperfect contact in master controller on some of the fingers of the primary cylinder. Third, two or more imperfect 4-ampere fuses in the control apparatus circuits.

Question 4. What should be done to detect imperfect master controller fuse?

Answer. Open main master controller switch and renew fuse, and if there is still no operation of contactors the trouble is evidently elsewhere.

Question 5. How can an enclosed fuse that has blown be detected?

Answer. A small circle in center of table is charred and turned black when fuse is blown. This is termed the "Telltale" of fuse.

Question 6. What should be done to detect imperfect contact in master controller?

Answer. Cut out master controller switch, then remove controller cover and open arc deflectors; first on the right-hand side. Turn on controller and see that the controller fingers make good contact with their respective cylinder segments. If any contact is imperfect endeavor to readjust, if there is time. Failing in this go to the other controller and operate from that, after cutting in its overhead switch and the main master controller switch again.

Question 7. What should be done to detect imperfect fuses in the control apparatus circuits?

Answer. Remove cover from the cut-out switch on back of No. 2 controller and inspect the five top fuses and the eighth and ninth from top. If any one of these fuses shows signs of being blown from the telltale being black, renew the blown fuses.

Question 8. If some of the contactors close on the first test without giving main current, what should be done?

Answer. After opening main switch throw reverser handle back and forth two or three times,. throwing controller to first notch at each reversal and note whether both reversers respond, throwing over at each reversal.

Question 9. If neither reverser responds, what should be done?

Answer. Renew fuses eighth and ninth from top on cut-out switch and then try.

Question 10. If one reverser responds to reversals on controller and other does not, what should be done?

Answer. Throw over by hand the reverser that is not operating, making sure after throwing that the reverser is properly locked by toggle. It would require considerable force to lock reverser, but it is absolutely essential that it be locked, and no attempt should be made to operate before making sure of this.

Question 11. What contactors should close on the first notch of controller?

Answer. 1, 2, 4, 19, 22, 25, 33, 41 and 42. Contactors 1, 4 and 19 close after No. 1 reverser thrown; 25, 33 and 41 close after No. 2 reverser throws. Contactors 2, 22 and 42 are governed by the No. 1 circuit on master controller.

Question 12. If contactors 2, 22 and 42 do not close, what should be done?

Answer. First, renew top 4-ampere fuse on cut-out switchboard. Second, examine main motor cut-out switches. See that they are well closed, so that auxiliary contacts are closed.

Question 13. If this is not effective what should be done?

Answer. After closing main switch again throw controller to eleventh notch, moving slowly from tenth to eleventh, and begin operation in series multiple. Motorman should here move handle more slowly than ordinarily, as the automatic feature may thus be cut out. Motorman should watch meter and should not exceed 2,000 amperes in multiple.

Question 14. If two locomotives are being operated together and the master controller fuse blows again, after being removed, what should be done?

Answer. Pull 20-point jumper between locomotives and try renewing fuses, and then operate from locomotive on which fuse does not blow again. If a new 20-point jumper is available this may be substituted and tried.

Question 15. If motors do not take current between eleventh and seventeenth notches or between the eighteenth and twenty-fourth notches, what should be done?

Answer. Renew the second and fifth fuses for the first case and the second and fourth fuses for the second case. If this is not effective examine contact fingers for the primary cylinder and adjust if any of these fingers are not making good contact. Failing in this operate from the other controller.

Question 16. What are the other causes that would prevent the operation of locomotives?

Answer. First, the blowing of the third-rail shoe fuses. Example for this, if lights are not obtainable in turning on light switches (see Q. 2). Second, the blowing of an individual motor fuse.

Question 17. What would tend to reduce the speed?

Answer. First, in operating with two locomotives, if either locomotive is inoperative from any of the causes referred to, or if there is a loose 20-point jumper, or the bus line jumper is loose or out, and the shoe fuses blow on either locomotive, of course one locomotive would be dead load. Second, imperfectly acting triple, as would be indicated by meters showing excessive current.

Question 18. What should be done in the event of third-rail shoe fuses blowing?

Answer. These fuses will ordinarily blow only when there is a short circuit on locomotive equipment. If the cause of fuses blowing is evident, however, as from the

temporary grounding of a shoe, the fuse may be renewed after the ground has been removed. To do this put slipper boards under all the contact shoes of both locomotives and pull bus line jumper between locomotives and release overhead shoes from overhead rail. In removing slippers from under shoes, after renewing fuses, do not stand nearer the fuse box than is absolutely necessary. If one locomotive is grounded and the other is not, leave out bus line jumper and operate from locomotive which is free from ground.

Question 19. What should be done in case of an individual motor fuse blowing, as indicated by contactors 1, 2, 4, 19, 22, 25, 33, 41 and 42 closing properly on first notch without taking current?

Answer. After making sure that the motor cut-out switches over reversers are all closed, open main switch and see which motor fuse is blown, renew this and proceed. If this fuse blows again open cut-out switch for this motor and start train from the eleventh notch.

Question 20. If a third-rail shoe support is broken, what should be done?

Answer. Motorman should first pull bus line jumper if two locomotives are coupled together, insert wooden insulating slippers between the contact shoes and rail on the crippled locomotive and retrieve overhead shoe if upon rail and then proceed to detach or tie up remnant of device, exercising extreme care that the contact device is kept clear of the contact rail and kept clear of truck or any grounded part to prevent injury to himself.

Question 21. What should be done in case air pump fails to operate?

Answer. Renew fuse in pump switch which is located

in "A" end cab. Open the pump switch before doing this. If this does not remedy the trouble inspect the governor contacts and adjust them if necessary.

While many of the conditions referred to are somewhat imaginary and may never arise in practice, the questions and answers given should, however, serve to give the motormen familiarity with the circuits and the operation of the control.

After the motormen have acquired familiarity and experience in electrical operation, they may on occasion exercise their own judgment and common sense to better advantage.

AUTOMATIC AIR-BRAKE CATECHISM.

MOTOR CARS.

A.—General.

Question 1. What is the power used to operate an air-brake?

Answer. Compressed air.

Question 2. How is the air compressed for use in the brake system?

Answer. By air compressors on the motor cars.

Question 3. How does it apply the brake?

Answer. By being admitted to a brake cylinder and forcing a piston out, which, by means of connecting rods and levers, pulls the brake shoes against the wheels.

Question 4. How is the brake released?

Answer. By allowing the air in the brake cylinders to escape to the atmosphere. A spring in the brake cylinder then shoves the piston back and the brake shoes are forced away from the wheels by the brake release springs on the trucks.

Question 5. What is the form of air-brake now generally used?

Answer. The quick-action automatic brake.

Question 6. Why is it called an automatic brake?

Answer. Because if anything, no matter what, causes a reduction of pressure in the brake pipe, the brake will apply automatically.

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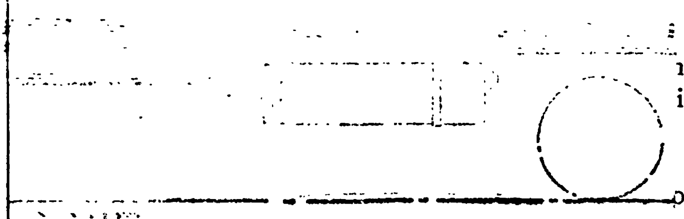

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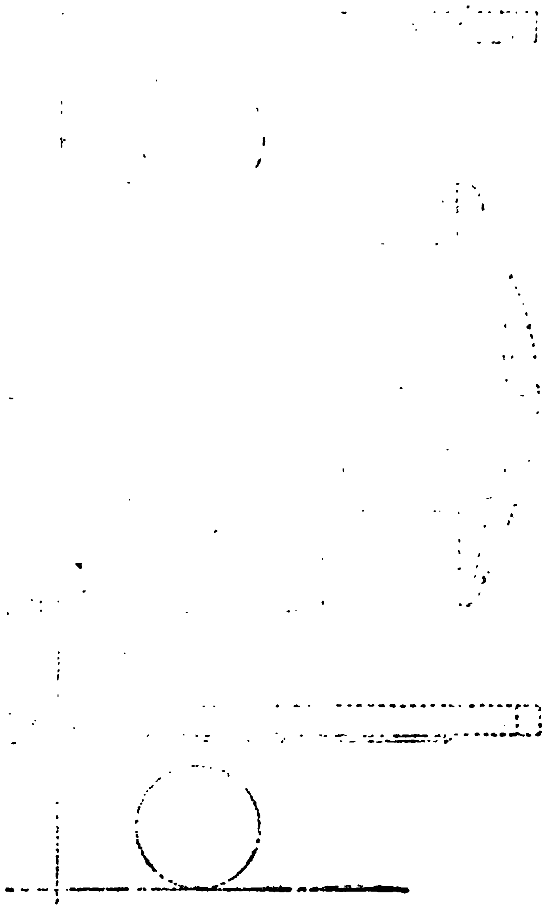


Question 7. What parts has the quick-action automatic brake on a motor car?

Answer. An air compressor, pump governor, two main reservoirs, safety valve, slide-valve feed valve, control pipe, two brake valves, two air gauges, brake pipe, triple valve, auxiliary reservoir, brake cylinder, conductor's valve, two air strainers, one bleed cock, two pair of hose and couplings, six cut-out cocks, one double cut-out cock, one air strainer with check valve, and one branch pipe air strainer (Fig. 524).

Question 8. Where are the brake valves and air gauges located?

Answer. In the motorman's cab at each end of the car.

Question 9. What parts has the quick-action brake on a trailer car?

Answer. Auxiliary reservoir, brake cylinder, triple valve, brake pipe, control pipe, conductor's valve, two air strainers, one bleed cock, four cut-out cocks, two pair of hose and couplings, one double cut-out cock, one air strainer with check valve, and one branch pipe air strainer.

Question 10. Is there any difference between the reservoirs, triple valves, and brake cylinders used on motor cars and trailer cars?

Answer. No.

Question 11. Where is the pressure that supplies the brake cylinder stored or carried with the automatic system?

Answer. In the auxiliary reservoir under each cab.

Question 12. What has to be done to apply the automatic brake?

Answer. Reduce the brake-pipe pressure, which reduction causes the triple valve to admit the pressure from the auxiliary reservoir to the brake cylinder.

B.—The Air Compressor.

Question 13. Where is the compressor installed, and how?

Answer. It is placed under the car, suspended from the sills by a cradle. (See Fig. 525).

Question 14. Does it make any difference in which direction the compressor rotates?

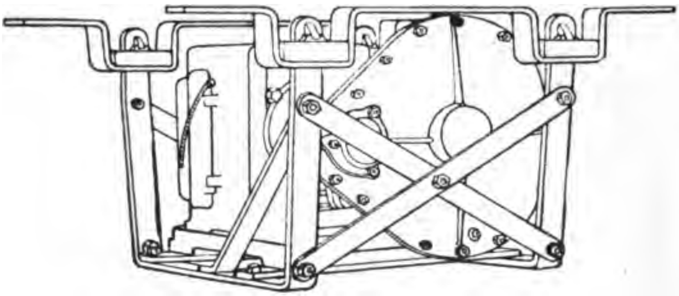


Fig. 525. Suspension Cradle of Air Compressor.

Answer. The shaft must always turn so that the compression part of the stroke is on the upper half revolution. This will be assured if the rotation is the same as the hands of a clock when looking at the compressor at the gear side.

Question 15. How are the pump parts lubricated?

Answer. The crank case is filled with oil (preferably Arctic Ammonia Oil) up to a point determined by the oil fitting 18, Fig. 526, on the side of crank case. When the level of the oil is visible in this fitting, the cap being removed, the oil level in the crank case is correct. As

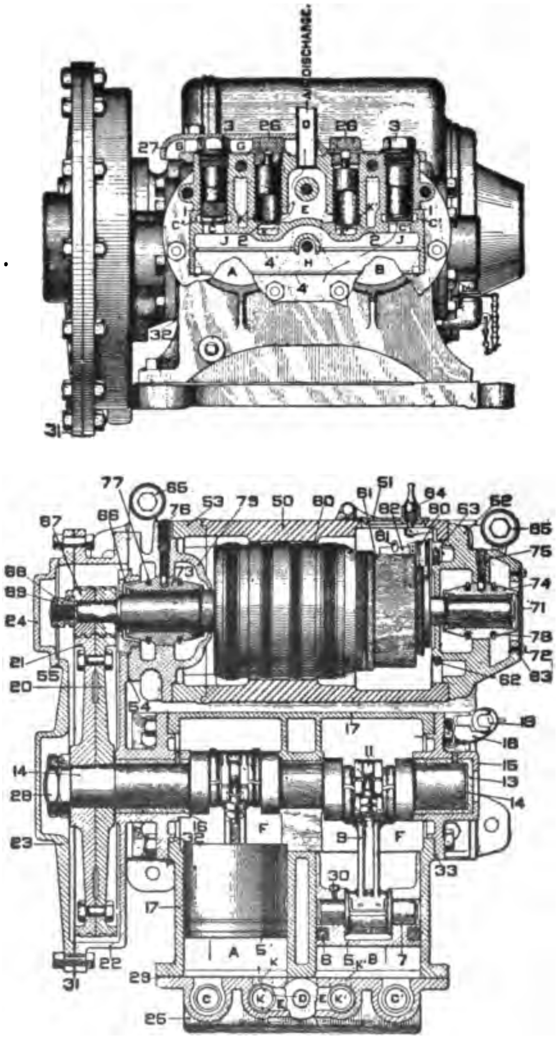


Fig. 526. Air Compressor on Motor Cars.

the shaft turns and the connecting rod heads are forced downward, they drive the oil over the inside of the crank case and such parts of the cylinders as are exposed. In this manner all the crank-shaft bearings as well as the cylinders themselves and wrist pins are thoroughly lubricated.

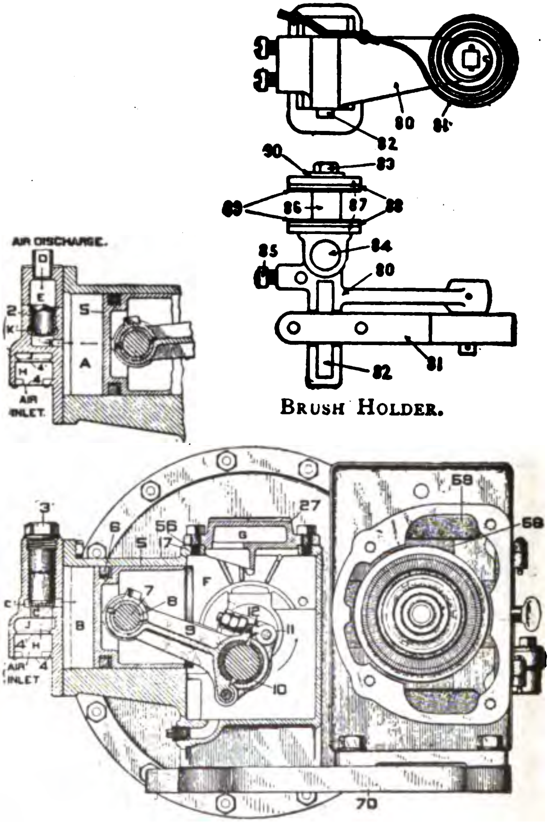


Fig. 527. Air Compressor on Motor Cars.

Question 16. How often should the oil in the crank case be replenished?

Answer. Once a week.

Question 17. How often should the suction box be cleaned?

Answer. This depends largely upon the locality in which the car operates. Generally it is not required more than once or twice a month. In very dusty localities it may be required oftener.

Question 18. How is the suction box cleaned?

Answer. The outer perforated plate 4 (Fig. 527) covering the air inlet on the lower side of chamber H should be removed and the pulled curled hair taken out and thoroughly cleaned by beating in a bag, by the use of compressed air or some other efficient means. It may then be replaced and the outer perforated plate put back in place.

Question 19. How is the motor lubricated?

Answer. By removing plug 65 (Fig. 526) in both end bearing housings and filling with oil until the level can be plainly seen. These bearings should be replenished at the same time as the crank case.

Question 20. Should a compressor which frequently blows fuses be sent out temporarily with a heavier fuse than that prescribed?

Answer. Not under any circumstances. Such a practice is almost sure to result in burning out the motor.

C.—Electric Pump Governor.

Question 21. What is the purpose of the electric pump governor? (Fig. 528).

Answer. It starts and stops the compressor automatically when certain predetermined minimum and maxi-

mum air pressures occur in the main reservoir by alternately making and breaking the circuit to the air-compressor motor.

Question 22. Where is this governor located?

Answer. It is placed in a sheet-iron box under the

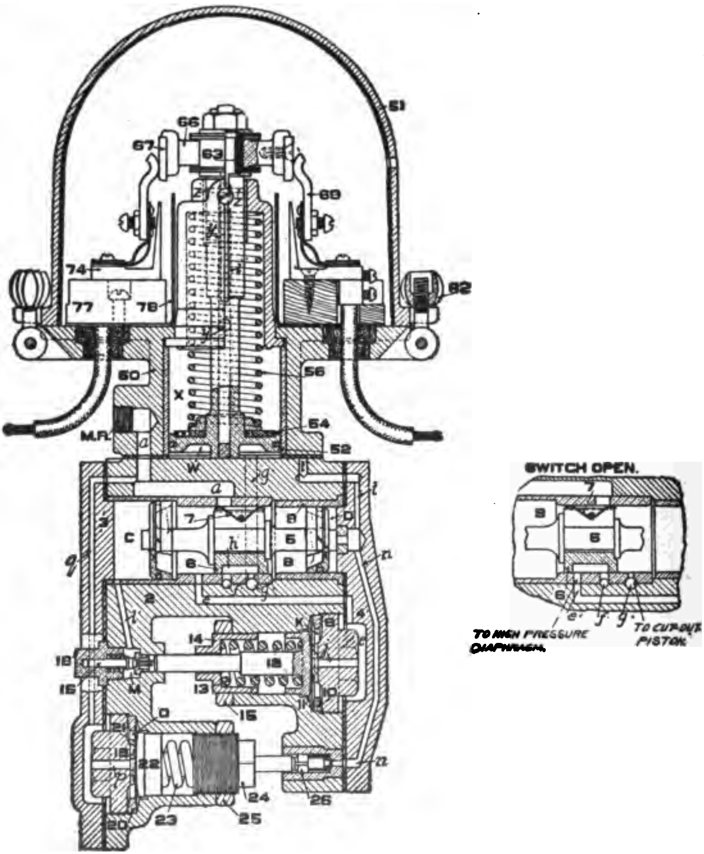


Fig. 528. Air Compressor Governor on Motor Cars.

car on the motor compressor side. This box is located between the grid resistances.

Question. 23. At what pressure is the governor set to start the compressor?

Answer. One hundred and five pounds.

Question 24. At what pressure is the governor set to stop the compressor?

Answer. One hundred and twenty pounds.

Question 25. Why is there such a difference between the maximum and minimum pressures?

Answer. By having this difference a number of applications of the brake can be made before reducing the main reservoir pressure to the cutting-in point. This gives the compressor a longer rest between periods of operation, thereby allowing it more time to cool.

D.—The Main Reservoirs.

Question 26. From the compressors where does the air pressure go?

Answer. To the main reservoirs.

Question 27. Where are the main reservoirs located?

Answer. Under each motor car.

Question 28. How much main-reservoir pressure should be carried?

Answer. One hundred and twenty pounds maximum and 105 pounds minimum.

Question 29. How often should the reservoir be drained?

Answer. Daily.

Question 30. From the main reservoir where does the air go?

Answer. Through the feed valves to the control pipe and thence to the motorman's brake valve.

E.—Safety Valve.

Question 31. What is the purpose of the safety valve? (Fig. 529).

Answer. It prevents overcharging of the brake system in case the electric pump governor fails.

Question 32. Where is it placed?

Answer. In the end of the main reservoir.

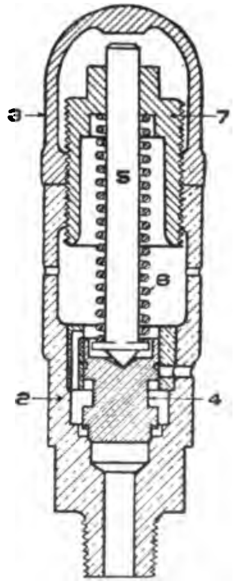


Fig. 529. Safety Valve.

F.—Slide-Valve Feed Valve.

Question 33. From the main reservoir, where does the air go?

Answer. To the slide-valve feed valve (Figs. 530 and 531).

Question 34. Where is it located?

Answer. In the box under the car between the resistances on the motor compressor side, in which the electric pump governor is also located.

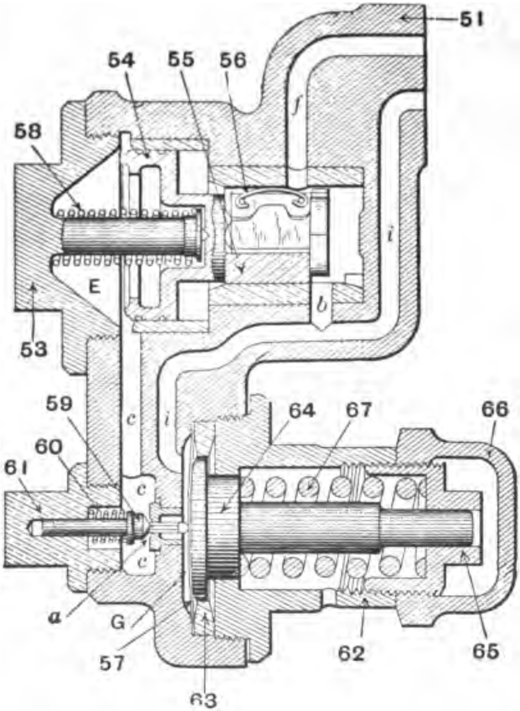


Fig. 530. Slide Valve—Feed Valve Open.

Question 35. What is meant by the slide-valve feed valve?

Answer. It is a device in the pipe from the main reservoir to the control pipe which automatically reduces

main-reservoir pressure to a constant control-pipe pressure.

Question 36. What tends to lower the control pipe pressure, thereby causing the slide-valve feed valve to act?

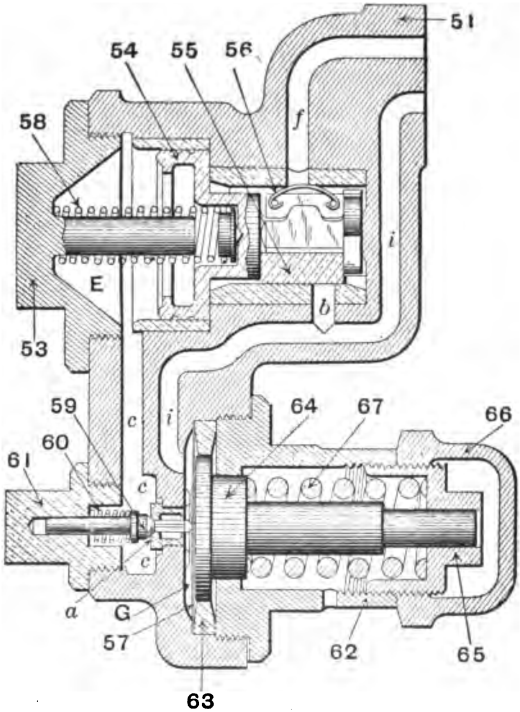


Fig. 531. Slide Valve—Feed Valve Shut.

Answer. Reinstating the brake-pipe pressure at release; recharging the auxiliary reservoirs; maintaining an air pressure of 90 pounds in the system against leakage, when the brakes are not applied.

Question 37. What care should be given this feed valve?

Answer. The piston and its slide valve should occasionally be taken out, all dirt and gum removed from them and the chambers where they work, being careful to leave no lint and to avoid bruising the parts removed. A very small amount of some light lubrication oil (engine oil will do in the absence of a better) should be applied to the piston, the face of the slide valve and the spring on the latter. In replacing the parts move them back and forth a few times to insure that they work freely. Next, remove the regulating valve, carefully clean it, its valve seat and the bushing through which the valves extend, using no metal to do this, so as to avoid scratching, and replace the valve dry.

Question 38. Must the main reservoir be drained to do this?

Answer. No. Close the cut-out cock between the feed valve and the main reservoir.

Question 39. When properly regulated, what can cause pressure to feed too high in the control pipe?

Answer. A leaky slide valve.

Question 40. What will tend to prevent the feed valve properly maintaining the pressure in the control and brake pipes?

Answer. A leaky regulating valve, leakage past cap nuts. If this leakage is great enough the effect will be the same as opening the regulating valve.

Question 41. What will tend to prevent the feed valve from opening promptly?

Answer. The piston becoming heavily coated with a greasy deposit, which prevents rapid equalization of the

pressure on both sides of the piston, thus reducing its sensitiveness.

Question 42. Should the feed valve be carefully regulated?

Answer. As there are a number of these valves in a train they should all be regulated alike as nearly as possible, since that valve which is regulated the highest will stay open the longest and furnish the most air, thus making the work imposed on the compressor of that car more than that done by the others.

G.—Control Pipe.

Question 43. After leaving the feed valve, where does the air go?

Answer. Through the control pipe to the brake valve that is being operated by the motorman.

Question 44. What is the purpose of the control pipe?

Answer. It is the means of conveying to the brake valve that is being operated by the motorman the supply of air furnished by all the main reservoirs of the train.

Question 45. What are the connections to the control pipe?

Answer. From the feed valve; to the brake valve, and to the triple valve.

Question 46. What pressure is maintained in the control pipe?

Answer. Ninety pounds.

Question 47. Does this pressure vary during the application of the brakes?

Answer. No.

H.—The Motorman's Brake Valve.

Question 48. From the feed valves, where does the air go?

Answer. Through the control pipe to the brake valve being operated by the motorman.

Question 49. From the feed valves to the control pipe to the brake valve is all what pressure?

Answer. Ninety pounds.

Question 50. It passes through the brake-valve into what?

Answer. The brake pipe, and thence through the triple valve to the auxiliary reservoir.

Question 51. What is the purpose of the brake valve?

Answer. To connect the control pipe to the brake pipe; to release the brakes, charge the system and maintain the pressure; to connect the brake pipe through suitable passages to the atmosphere to apply the brakes, and to break all connection between the brake pipe and control pipe or atmosphere; to hold the brakes applied.

Question 52. In what position of the brake valve is there a direct opening from the control pipe to the brake pipe?

Answer. In release or running position.

Question 53. In this position how would the control pipe and brake-pipe pressure stand, comparatively speaking?

Answer. Equal.

Question 54. What is the release or running position to be used for?

Answer. For recharging the brake pipe quickly, so as to insure a prompt and simultaneous release of the

brakes; for recharging the auxiliary reservoir, and prevent brake-pipe leakage from setting the brakes.

Question 55. What is the next position of the brake valve and what does it signify?

Answer. Lap position; all ports closed.

Question 56. When is it used?

Answer. When holding the brakes on after an application; or when graduating the release; or when they have been applied by opening a conductor's valve. This position should also be promptly used when train breaks in two; hose becomes uncoupled or bursts; when coupling to air-brake cars or at any time a sudden reduction of brake-pipe pressure takes place when not made by the motorman himself.

Question 57. How should the brake-valve handle be turned to lap?

Answer. Slowly after making a brake-pipe reduction so as to cut off the exhaust gradually, that the head brakes will not be "kicked off" by the air surging forward; quickly when going to the release position, to graduate the release.

Question 58. Why should it be returned quickly when graduating the release?

Answer. Because the longer the brake-valve handle is in the release position the lower the brake-cylinder pressure will reduce. In other words, the reduction of brake-cylinder pressure is governed by the same principle as the increase of brake-cylinder pressure during an application, but oppositely. For example, the increase of brake-cylinder pressure up to the point of equalization is proportional to the decrease of brake-pipe pressure; on the other hand, the decrease of brake-cylinder pressure is proportional to the increase of brake-pipe pressure.

Question 59. What is the next position and its use?

Answer. Service application; should be used for all ordinary stops.

Question 60. How is the air discharged from the brake-pipe in making a service application?

Answer. Through ports in the rotary valve of the brake-valve, and the "quick service" ports of the triple valve. The further the brake-valve handle is moved in the service-application direction the more rapid the discharge of air.

Question 61. Would the blow, or escape, of air from the brake-pipe be longer with a six-car train than with a three-car train, the same reduction in pounds being made in each case?

Answer. Yes; if the brake-valve handle is moved to the same notch in both cases. The capacity of the long brake-pipe being so much greater it would require a larger volume of air to escape to make the same reduction in pounds.

Question 62. How many service-application notches has the brake-valve?

Answer. Two: service and intermediate service.

Question 63. When should they be used?

Answer. With a six-car train the brake-valve handle can be moved to the second service-application opening, but with not more than three or four cars the first or intermediate notch should be used.

Question 64. Why not use the service notch with a three or four-car train?

Answer. Because owing to the comparatively short brake-pipe the reduction of brake-pipe pressure would be sufficiently rapid to cause quick action, resulting in a full emergency application of all the brakes when only partial service application was intended.

Question 65. What is the next position?

Answer. The emergency or quick-action; in this position a large direct opening is made from the brake-pipe to the atmosphere.

Question 66. When is this position to be used, and how?

Answer. Only in case of emergency; and then the handle should be moved directly to that position and allowed to remain there until the train stops or the danger is passed.

I.—Brake-Pipe.

Question 67. What is the purpose of the brake-pipe?

Answer. It is the connection between the brake-valve and the triple valves, auxiliary reservoirs and brake cylinders.

Question 68. What is the difference in pressure between the brake-pipe and the control pipe?

Answer. When the brake-valve handle is in full release there is no difference; during an application of the brakes the brake-pipe pressure is lower than the control pipe, an amount depending on what brake-pipe reduction is made by the motorman.

Question 69. What special devices are placed in the connection from the brake-pipe to the triple valve?

Answer. The double cut-out cock and the branch-pipe air strainer.

Question 70. What is the double cut-out cock?

Answer. It is a cock having two entirely separate passages through it, one tapped at each end for one-inch pipe and the other for three-eighth-inch pipe. The larger one is for the branch pipe from the brake-pipe to the

triple valve, and the smaller one for the branch pipe from the control pipe to the triple valve. The turning of the cock handle shuts off communication from both the brake-pipe and the control pipe to the triple valve. (Fig. 532).

Question 71. Why should it be arranged to shut off communication from both the brake-pipe and the control pipe to the triple valve at the same time?

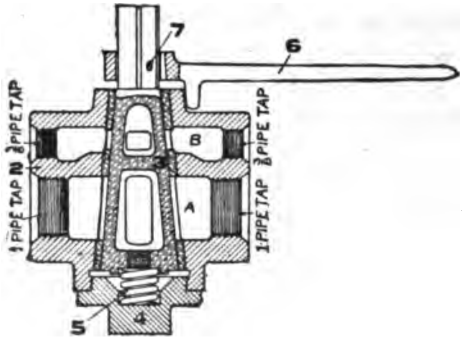


Fig. 532. Double Cut-out Cock.

Answer. It makes it impossible in case anything should happen to the brake cylinder, reservoir or triple valve to cut them out from one of these pipes and not from the other, which might easily occur if a single cock were placed in each of the branch pipes separately.

Question 72. When is the double cut-out cock to be closed?

Answer. Only when the brake apparatus on that car becomes out of order sufficiently to make it inadvisable to use it.

Question 73. What is the purpose of the branch-pipe air strainer?

Answer. It prevents dirt and scale from entering the triple valve, where it might result in cutting the slide valve and piston; or during an emergency application lodge on the emergency valve and hold it open.

Question 74. How are connections made between the cars?

Answer. By hose and couplings.

Question 75. What is it necessary to do when coupling or uncoupling hose connections between cars?

Answer. To uncouple it is necessary first to close the cocks at the end of each car, both for the brake-pipe and the control pipe, before attempting to uncouple the hose. In coupling it is necessary to see that the hose couplings for both the pipe lines are securely made before opening the cocks in each pipe on the cars; open the cocks of the control pipe FIRST, and AFTERWARDS those in the brake-pipe.

Question 76. In making up trains what should be done with the hose couplings at each end of the train?

Answer. They should be fastened up to the dummy couplings which are supported on the end of the car in order to keep any dirt or foreign matter from getting into the couplings and pipes, and to prevent anything lying in the track from striking them. Also, to reduce the wear due to the swinging of the hose when free.

J.—The Triple Valve.

Question 77. To what is the brake-pipe connected under the car?

Answer. The triple valve.

Question 78. Where is it located?

Answer. On a bracket in a special box underneath the car, between the grid resistances, on the side opposite to the box containing the electric pump governor and feed valve.

Question 79. Why is it called the triple valve?

Answer. Because of the three distinct operations it performs in response to variations of brake-pipe and auxiliary reservoir pressures. It (1) charges the auxiliary reservoir; (2) applies, and (3) releases the brakes.

K.—Auxiliary Reservoir.

Question 80. What is the auxiliary reservoir?

Answer. It is a wrought steel reservoir in which is stored the air for applying the brakes on the car to which it is attached.

Question 81. To what is it connected?

Answer. Its only connection is to the triple valve.

L.—Brake Cylinder.

Question 82. What is a brake cylinder?

Answer. It is the cylindrical casting secured to the car framing at the side of the auxiliary reservoir. It is provided with a piston having an air-tight leather packing and a hollow piston rod. This piston, together with the cylinder and the head on the packing leather side, form a chamber into which the compressed air is admitted from the triple valve, and by forcing the piston outwardly applies the brakes to the wheels by means of foundation brake gear and brake shoes to which it is attached by a loose push rod; a head on the other end of the cylindrical casting forms the guide for the piston and a seat for a coiled spring by which the piston is forced

back to the inner end of its stroke when the air pressure is exhausted from the brake cylinder by the operation of the triple valve.

M.—Levers.

Question 83. How is the piston rod connected to the brake shoes?

Answer. By a system of levers generally called "foundation brake gear." When the piston is pushed out the levers are so arranged as to draw the shoes up against the wheels. (Fig. 533).

Question 84. What is especially necessary in arranging these levers?

Answer. That the retarding effect on each wheel should be in proportion to the weight of the car bearing upon it and that it should be equal for both wheels on the same axle. When a car weighs equally on all the axles the brake-shoe pressure should be equal on all the wheels.

Question 85. How is the necessary brake-shoe pressure against the wheels determined?

Answer. By the light weight of the car.

Question 86. What proportion of light weight is taken as a basis for the brake-shoe pressures?

Answer. The total pressure of the brake-shoes against the wheels should be 100 per cent of the weight of the motor cars and 90 per cent of the light weight of the trailer cars.

Question 87. What is the general arrangement of foundation brake gear?

Answer. Fig. 533 shows the general arrangement of brake rods and levers and their relation to the brake

cylinder. To the push rod is connected the PUSH-ROD LEVER. A similar lever, called the CYLINDER LEVER, is attached to the slack adjuster and connected with the push-rod lever by the CYLINDER ROD. Through these two levers the pressure developed in the brake cylinder is carried to each of the trucks. As the piston is pushed out by the air pressure the upper end of the push-rod lever is forced to the left. This transmits the force through the cylinder rod to the cylinder lever, and as a result the lower ends of both levers are drawn together, transmitting a pulling force through both of the TRUCK PULL RODS. The push-rod and cylinder levers are so proportioned that the amount of force transmitted to each truck is in the same proportion as that of the weight of the car resting on each truck. The amount of pull transmitted to each of the truck pull rods is equal.

The truck pull rod engages with the upper end of the LIVE TRUCK LEVER. The lower end of the live truck lever is connected with the lower end of the DEAD TRUCK LEVER by a TIE ROD. These truck levers are proportioned, so that each brake beam gets an amount of pressure in proportion to the weight on that axle.

Question 88. What is the total leverage?

Answer. It is the ratio* of the sum of the pressures on all the wheels of the car to the pressure on the push-rod.

Question 89. How is the hand-brake connected to the lever system?

Answer. Through the HAND-BRAKE ROD, HAND-BRAKE LEVER, HAND-BRAKE CONNEC-

*Ratio: The quotient obtained by dividing one into the other is obtained. Suppose it is 7. Then we say the ratio is 7 to 1.

TION, MULTIPLYING LEVER, and the chain which connects the multiplying lever to the push-rod.

Question 90. What is the use of the chain?

Answer. It provides a flexible connection between the hand-brake and power-brake rigging, so that when the power brake is in operation the hand-brake levers do not move, thus reducing the amount of friction to be overcome by the air pressure and also reducing the wear on the hand-brake rods and levers.

Question 91. What is the object of the multiplying lever?

Answer. To increase the power of the hand-brake to that ordinarily obtained by the air pressure.

Question 92. When applying the brakes by hand does the piston in the brake cylinder move out?

Answer. No. The push-rod is loose in the push-rod holder and can be forced out by the piston, but cannot pull the piston out when it is pulled out.

N.—General Operation.

Question 93. How should brakes be tested in preparing trains for service?

Answer. First, see that hose coupling cut-out cocks on the head and rear end of train are closed and those between the cars are opened. Next, that all the brake valves are lapped with the exception of the one that is to be used, and this must be placed in release position. Then start the compressors, charge the brake-pipe and auxiliary reservoirs, allowing the compressor to operate until the governor cuts it out. Motorman will then apply brakes by moving handle of brake valve to service-application notch until a reduction of ten pounds has been

made in the brake-pipe. Then after placing handle on lap, remove handle, and carrying same, motorman will proceed throughout length of train and see that each cylinder piston of every car has moved out such a distance as to indicate that brakes are properly applied on all cars of the train. The brakes are then to be released from the last cab at end of train. Then again remove handle, and return to other end of train, examining all cylinder pistons. Be careful to see that they have moved back to full release, thus indicating that all brake shoes hang free.

Question 94. In making an application of the brakes for any purpose, except testing brakes or emergency applications, what is the least pressure that should be drawn from the brake-pipe at the first reduction?

Answer. Five pounds.

Question 95. Why not less than this amount?

Answer. Because the reduction might not be sufficient to force the brake piston against the release spring and friction of brake rigging.

Question 96. What reduction of train-line pressure is necessary to fully apply the brakes on service application?

Answer. From eighteen to twenty pounds.

Question 97. Why should the reduction, as stated in the last question, fully apply the brakes?

Answer. Because eighteen to twenty pounds reduction in brake-pipe pressure causes an equalization of auxiliary reservoir and brake-cylinder pressure, thus fully applying the brakes. A further reduction in the brake-pipe is simply a waste of air.

Question 98. What is the possible result of this waste of air?

Answer. The brakes are slower in releasing, fail to

release simultaneously, cause a shock to the train upon stopping, and seriously overtax the compressor.

Question 99. How many applications should be made in making the ordinary service stop?

Answer. As a general rule, one.

Question 100. What is meant by one application?

Answer. From the time the brakes are applied until they are fully released, no matter how many brake-pipe reductions or graduated releases, is one application; after the brakes have been fully released, and are reapplied, is a second application.

Question 101. How is the application to be made for an ordinary service stop?

Answer. A fifteen to eighteen-pound brake-pipe reduction should be made obtaining a full cylinder pressure at once, if at fair speed and gradually reducing same as the speed of the train decreases.

Question 102. Should this plan of operation invariably be followed?

Answer. No. If the train is drifting or running at very low speed it is not necessary to have such a high cylinder pressure.

Question 103. Why is it that the cylinder pressure should be gradually released as the speed of the train decreases?

Answer. Because the friction between the brake-shoes and the wheels is less for high speed than for low, having the same pressure in both cases. Consequently, if maximum cylinder pressure is used at a high speed it is necessary to decrease it as the speed decreases; also to make stop in less time and to avoid rough stops; also stops can be made much more accurately; otherwise, skidding of the wheels would be likely to follow at low speeds.

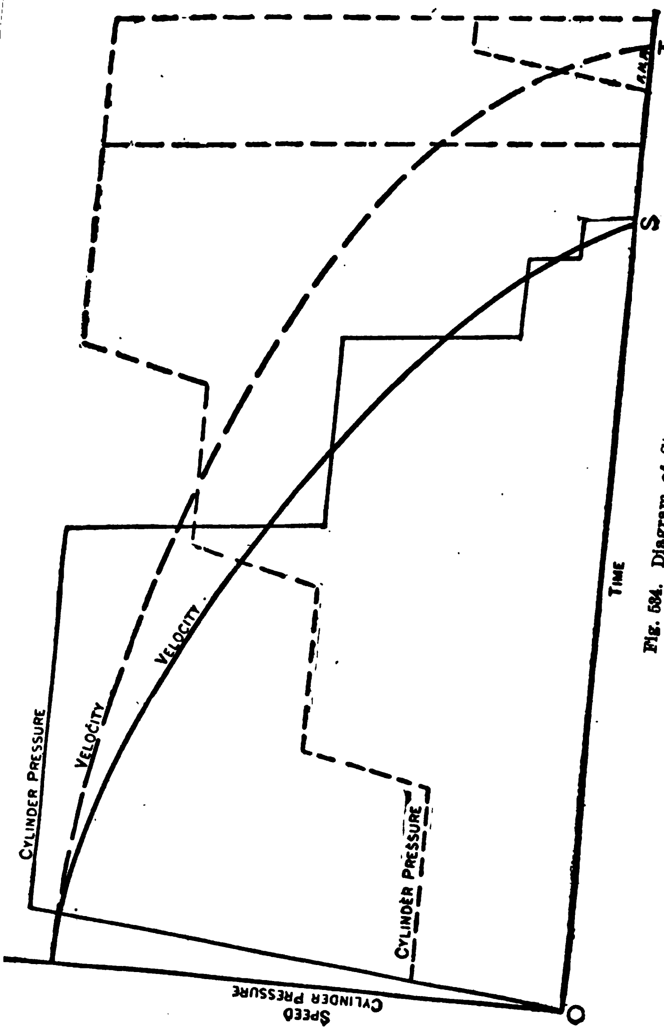


Fig. 534. Diagram of Stops.

Question 104. What would be the result if the cylinder pressure should be gradually increased during the application?

Answer. Pressure would be least when the speed was greatest, and, therefore, have a much smaller retarding effect than it ought to; and would be greatest when the speed was considerably reduced, thereby making the skidding of the wheels very probable and bring the train to a stop with a sudden jerk.

Fig. 534 illustrates the proper and improper method of handling the brakes in a service application. The brakes are applied at O and the train comes to a stop at S or T. The curve shows the decreasing velocity after the brakes are applied. The diagram shows the variations of cylinder pressure during the stop. The full lines show the proper method of handling, and the dotted lines the improper. It will be seen by the dotted diagram and curve that the retardation of the train during the first part of the stop is comparatively small. The motorman is afraid to put on his brakes, and as a result applies them little by little, till at the end of a stop he has full cylinder pressure, and the retardation of the train is very sudden and dangerous. Often motormen will find, when using such a method, that he has to make full release of the brakes and then reapply, as shown on the diagram, in order to keep the train from stopping short of the station. This causes jerks and uneven motion throughout the train and a great waste of air, resulting in overworking the compressor and causing unnecessary wear on the train apparatus.

On the other hand, if the motorman throws full pressure at once into the cylinder the retardation during the first part of the stop is much greater, and as the speed

gradually decreases, the motorman gradually releases the cylinder pressure in such a way as to keep the retardation of the train at a maximum. The amount gained in retardation during the first part of the stop by the proper method of braking makes the time required for the entire stop much less than in the other case, the time saved being represented by the distances S T.

Question 105. What other reason is there besides making quicker stops for using the proper method of braking outlined above?

Answer. By gradually releasing the brakes the auxiliary reservoirs are partially recharged at each partial release, till when the train comes to a stop the auxiliary reservoirs are almost completely recharged. In the other case, when the train comes to a standstill the brake-pipe pressure is the least of any time during the stop, so that the entire system has to be completely recharged after the train comes to a standstill. This means, in the latter case, more time is required for the brake system to be fully prepared for subsequent applications. Also with proper method start can be made quickly if desired, as there is little, if any, cylinder pressure remaining. This is also true if grade necessitates holding brake on during stop, as it can be graduated almost off.

Question 106. In making partial release during a brake application, how should the brake valve be handled?

Answer. It should be moved to the release position for a moment and immediately returned to lap.

Question 107. To make a complete release of brakes, how should the brake-valve be handled?

Answer. It should be moved to the full release position and allowed to remain there.

Question 108. If brakes release after a service-application, where should cause be looked for?

Answer. Examine brake valves in train until trouble is located. Either a brake-valve has not been fully lapped or has a leaking rotary valve.

Question 109. In case of emergency, when it is essential to stop the train in the shortest possible distance, how should the brake-valve be handled?

Answer. The handle should be thrown to the full emergency position and left there until the train has come to a stop, or the danger is passed.

Question 110. Would it not be better to return the handle to lap position after a quick reduction has been made? The object to save brake-pipe pressure to assist in releasing?

Answer. No. The first consideration in a case of emergency is to stop and to do that as quickly and surely as possible. The handle should be left in emergency position.

Question 111. If the motorman has the brake partially applied with service application and should be suddenly flagged, what should he do?

Answer. Put the valve handle in the emergency position and leave it there until stopped, the same as before.

Question 112. Would he get quick action under those circumstances?

Answer. That depends on the amount of reduction made in service and the length of the piston travel. With only a slight reduction he would get partial quick action, but would not get full quick-action brake-cylinder pressure.

Question 113. Could anything be gained by placing

the handle in release position for a moment before going to emergency position?

Answer. No; it would be dangerous to do so. Such an action would release the brakes when they were most needed and would make them slower to apply.

Question 114. If the motorman had the brakes applied with a thirteen to fifteen-pound service application, and was flagged, would it be policy for him to put the brake-valve in the emergency position?

Answer. Yes; if it were a case of emergency. Possibly some of the brakes have partially leaked off; the emergency application would set them fully.

Question 115. In the case of emergency should a motorman reverse his motors?

Answer. Yes. As a last resort to prevent collision or to save life he may reverse his motors. Handle on master controller should be thrown into opposite direction to the first, or switching notch, which notch is usually found to have the greatest retarding effect. Motors may also be reversed in the event of brakes being inoperative, but in ordinary service conditions motormen must never reverse motors.

Question 116. In case the brakes are applied suddenly from the train, what should the motorman do?

Answer. Place the brake-valve handle on lap position until a signal is given to release the brakes.

Question 117. Why is this done?

Answer. To maintain the main reservoir pressure and to prevent its escape, thereby providing for a prompt release of the brakes.

Question 118. How should the conductor's valve be operated when necessary?

Answer. It should be pulled wide open and allowed to

remain or be held in that position until the train stops, and then before leaving it the valve should be closed.

All cars have a conductor's valve which, when opened, remains in that position until closed by hand.

Question 119. Why is it necessary to leave the conductor's valve open until the train has stopped, if it is used?

Answer. Because if it is closed and the motorman fails to place the brake-valve on lap position the brakes will release.

Question 120. What does this valve do when it is open?

Answer. It makes a direct opening from the brake-pipe to the atmosphere, the same as when the brake-valve is placed in the emergency position.

Question 121. Can the brakes be released with the conductor's valve?

Answer. No. It must be remembered that to release brakes it is necessary to either put air into the brake-pipe or take it out of the auxiliary reservoirs. The conductor's valve will not do either of these.

Question 122. Should the brake apply suddenly, without the aid of the motorman or train crew, what should be done?

Answer. Place the brake-valve handle on the lap position as before.

Question 123. What would be the probable cause of this?

Answer. Either a burst hose, burst brake-pipe, or train breaking in two.

Question 124. In the event of a burst brake-pipe hose, what should be done?

Answer. Close the flat handled cut-out cock imme-

diately ahead of the burst hose and release the brakes back of the burst hose by closing the double cut-out cocks and opening the bleed cocks in the auxiliary reservoirs, leaving them open. The brakes ahead of the fractured hose can be released, provided the brake is still operative upon at least half of the cars in the train. If the motorman has control of less than half of the brakes of the train, the hand brakes on the cut-out cars must be applied to assist in controlling the train.

Question 125. In the event of a control-pipe hose bursting, what should be done?

Answer. Close the round-handled cut-out cocks immediately ahead and behind of the disabled hose, the brakes may then be operated in the usual manner until the train reaches the terminal, when the fractured hose must be replaced.

Question 126. Should the cross-over pipe connecting the brake-pipe and triple valve be broken, what should be done?

Answer. If the break is between the double cut-out cock and the triple valve, the double cut-out cock should be closed and the release valve opened under the disabled car. If the pipe is broken between the double cut-out cock and the brake-pipe, the flat-handled cut-out cock on the front end of the disabled car should be closed, release valves in all auxiliary reservoirs behind disabled car, as well as on that car opened, and the brakes operated the same as with the burst hose.

Question 127. If the brake pipe should be broken or burst, what should be done?

Answer. Close the cut-out cock on the front end of the car and operate brakes as per Answer 124.

Question 128. In setting off cars, what should be done?

Answer. The cut-out cocks should be closed first and the hose parted by hand and hung up properly.

Question 129. Should the hand-brake be set before releasing the air-brake?

Answer. No.

Question 130. What is the proper way to release a brake with a bleed cock?

Answer. The bleed cock should be held open until the exhaust air commences to escape from the triple valve; it should then be closed, as, if it is held open longer, it results in waste of air and has a tendency to set the other brakes.

Question 131. When it is permissible to cut out brakes on cars?

Answer. Only when they are in such condition to render it impossible to operate the brakes on such cars.

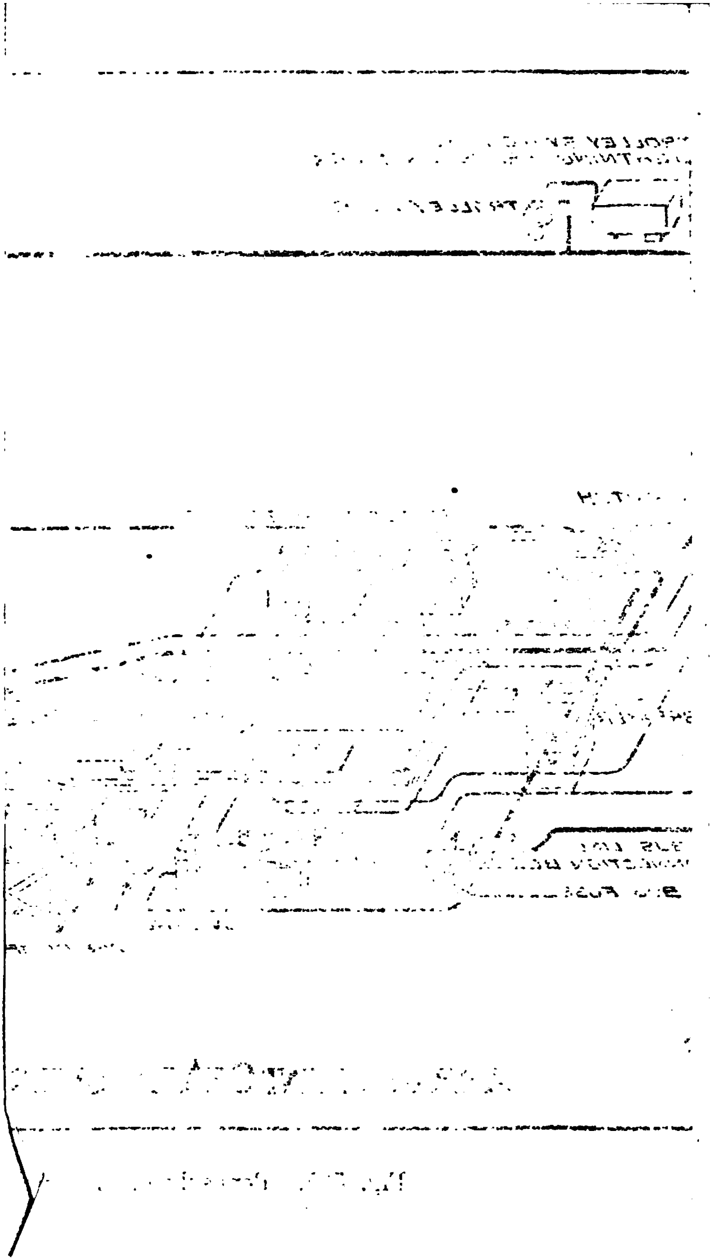
Question 132. Are small leaks sufficient cause for cutting out cars?

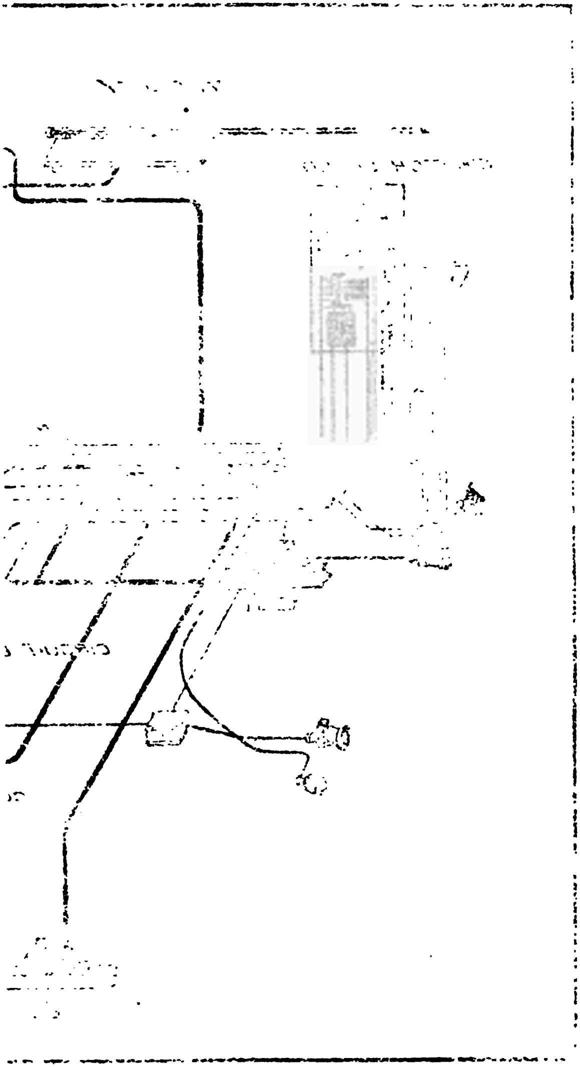
Answer. No.

In Fig. 535 is given the arrangement of the apparatus on a motor car of the West Jersey and Seashore R. R. Fig. 536 shows a slightly different arrangement of the apparatus on the motor cars of the New York Central.

The wiring of the apparatus is the same in both roads, and is proven by Fig. 537.

The arrangement of apparatus on the locomotives of the New York Central is shown by Fig. 538, and the wiring diagram in Fig. 539.





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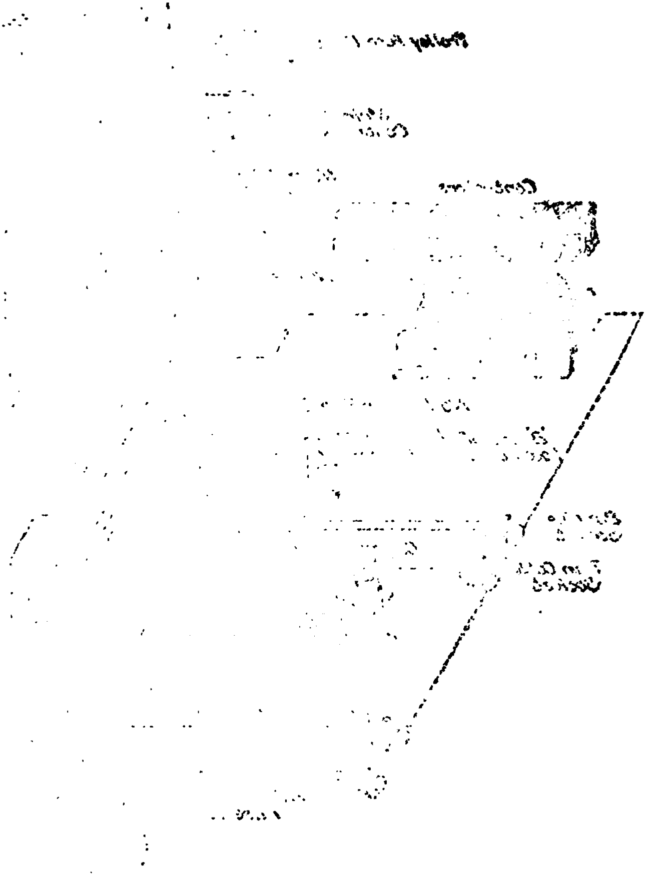

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